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Normal incidence - grazing incidence spectrograph for the vacuum ultraviolet

J. Kirston Henderson

NORMAL INCIDENCE - GRAZING INCIDENCE

SPECTROGRAPH

FOR THE

VACUUM ULTRAVIOLET

by

J. KIRSTON HENDERSON

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A

THESIS

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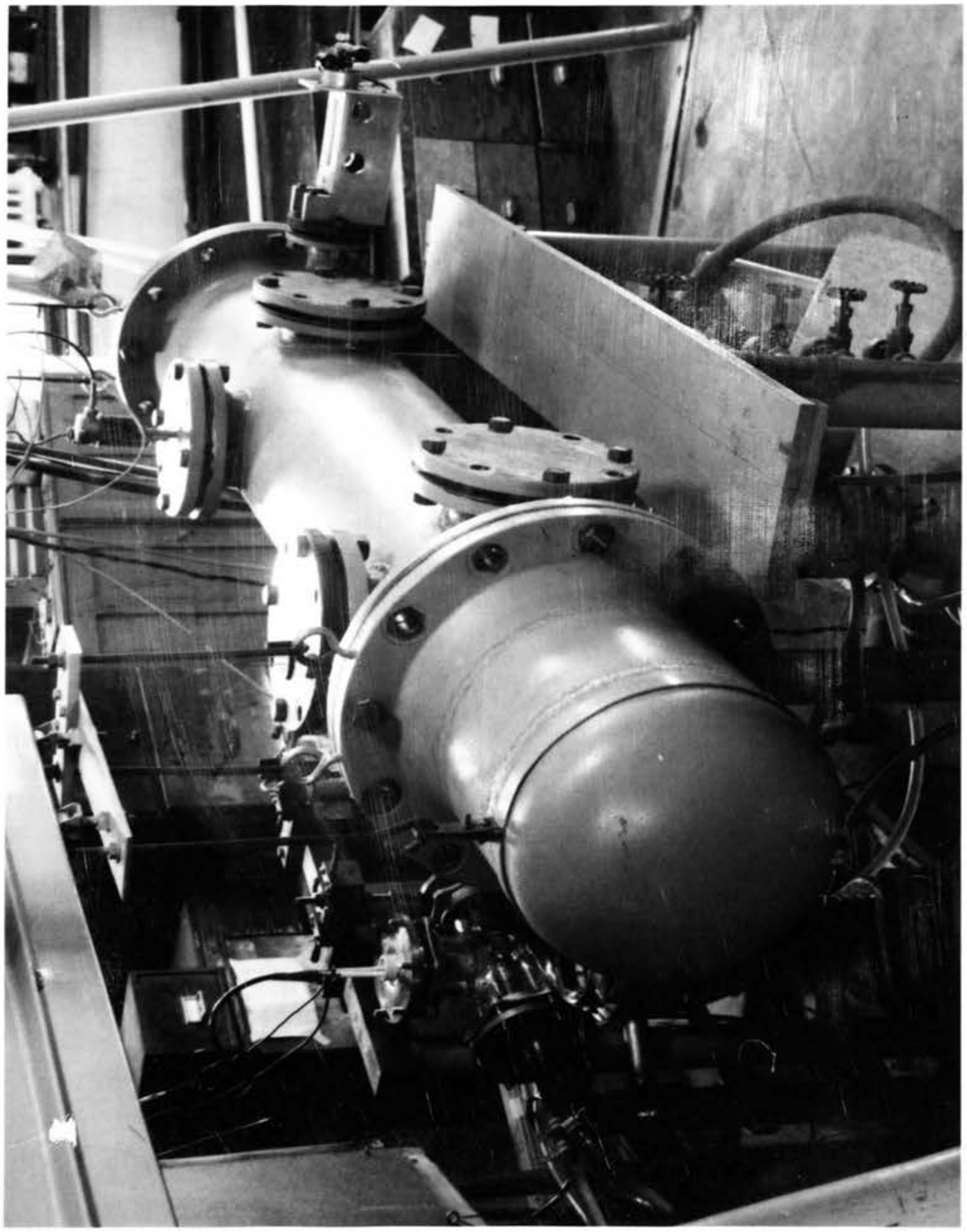

1.01.00: Acknowledgements

The author wishes to express his appreciation to Dr. Harold Q. Fuller for his advice and encourgement, to the MSM Mechanical Engineering and Drawing Departments for their cooperation and assistance, to Mr. Wendell Miller for his advice and assistance and to the Detroit Tool Company of Lebanon, Missouri for its cooperation in the construction of the vacuum chamber.

The author wishes to express his appreciation to his wife for her toleration of the stacks of drawings and paper during the completion of this thesis, to Miss Lindy Adams for her assistance in typing the final copy and to General Dynamics, Fort Worth for the reproduction of this document.

1.02.00: Preface

1.02.01: Presentation of Design

This thesis presents the design for a combination normal incidence - grazing incidence spectrograph for use in the vacuum ultra-violet and soft x-ray portions of the electromagnetic spectrum. The instrument described was designed and constructed as a partial fulfillment of the requirements for the master of science degree from The Missouri School of Mines and Metallurgy.

1.02.02: Design Details

Included in this thesis is a complete set of all detailed drawings and information required for either effective use or duplication of this instrument. Complete discussions of the design, operating procedures, difficulties encountered during construction and suggestions for future improvements are included.

1.02.03: Review of Vacuum Ultraviolet

A review of the general area of interest and work accomplished in the vacuum ultraviolet and circumstances leading to the design and construction of this instrument is included. (See section 3.00.00.)

1.03.00: Table of Contents

1.04.00: Table of Illustrations

Table of Illustrations (cont.)

Table of Illustrations (cont.)

1.05.00: Organization and Numbering System

1.05.01: Section Numbering System

Because of the length and nature of this thesis, a three digit pair numbering system is used throughout this thesis. For example, the number 1.05.01 identifies this paragraph as section one, sub-section five, item one of this thesis.

1.05.02: Page Numbering System

Pages are numbered in accordance with the section and sub-section to which they apply. In the event that more than one sub-section or item is included on the same page, the page carries two numbers stacked above each other in the upper right hand corner. For example, this is page 1.05.01, 1.05.05A. In the event that an item covers more than one page, the page numbers are followed by letters A, B, C,...

1.05.03: Figure Numbering System

Figures carry the number of the item to which they pertain followed by a letter. For example, if a figure were associated with this item, it would be numbered 1.05.03-A.

1.05.04: Page Numbers for Drawings

Part and assembly drawings in this thesis do not carry page numbers because they are adequately identified by the drawing numbers.

1.05.05: Part and Drawing Numbers

All assemblies, sub-assemblies and parts of the spectrograph are identified by a three digit pair of numbers of the same type used for section numbering. For example, part number 6.01.05 identifies the film backing band for the normal incidence film holder (assembly 6.01.00) which is a sub-assembly of film positioner and mask assembly 6.00.00. The part drawing for this part carries the number 6.01.05. This drawing follows drawing 6.01.00-A which in turn follows drawing 6.00.00-A, the cover drawing for assembly 6.00.00.

In order to keep drawing sheet sizes small and to provide systematic identification for all drawings and cover sheets, assembly drawings are followed by dash letters (i.e. dwg. 6.00.00-A). The significance of these dash letters is as follows:

Dash Letter	Significance
A	Drawing Control Cover Sheet, Fabrication and Assembly Notes
B	Front or Side View
C	Top View
D	Right End View
E	Left End View
F	Back View
G	Bottom View
H...	Auxiliary Views

In those instances in which the various views of an assembly are shown on separate sheets, a full, two, three, four, five or six view drawing may be obtained by placing the drawings as shown in figure 1.05.05-A.

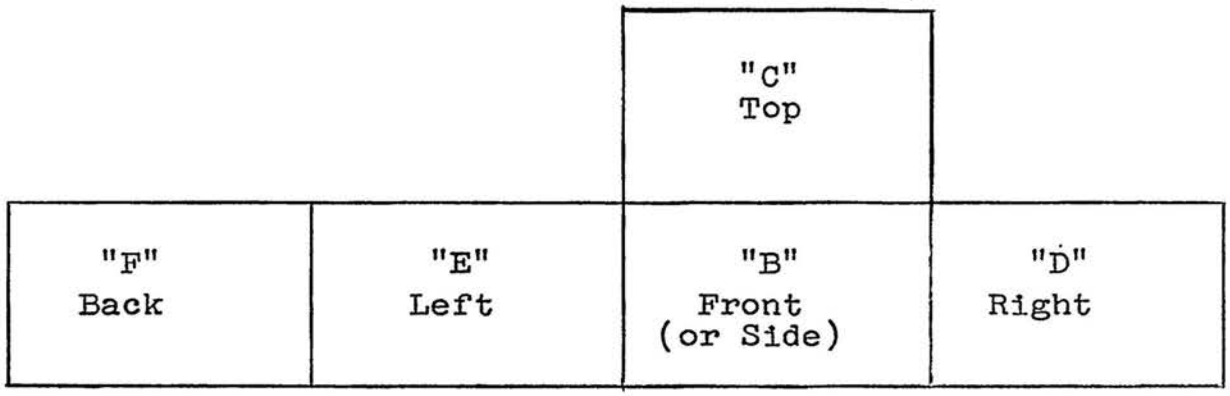

Figure: 1.05.05-A
Drawing arrangement for Full View

1.05.06: Dimensions and Tolerances

All dimensions are given in inches unless otherwise noted. Dimensional tolerances are given in decimal form in one of the following forms:

A. 16.250"

No tolerance shown means that the general tolerance shown at the bottom of the drawing applies.

B. 16.250"   0.005"

Tolerance is plus or minus 0.005 inches.

C. 16.255"
16.245"

Dimension is 16.250 inches. Tolerance is plus or minus 0.005 inches.

1.05.07: Materials

Material specifications are located at the bottoms of the part drawings.

1.05.08: Notes

In the event that applicable notes are not present on the drawing, they are located on the cover drawing "A". The cover drawing "A" should always be consulted for applicable fabrication and assembly notes.

1.05.09: Spectrograph Grid System

Points in the spectrograph are located by a system of grid lines. The station lines denote inches and thousandths of inches along the center line from the grating center. Station numbers are positive in the direction of the normal incidence plate holder. The position lines denote distances in inches and thousandths of an inch to either side of the center line. Position numbers are negative in the direction of the normal incidence light source side. Water lines give vertical distances from the grating center. The location of a point may be described by a set of numbers. For example, the grating center is described by (0.000, 0.000, 0.000). The first set of digits is the station line and the second is the position line. This same order is always used.

2.00.00: INTRODUCTION

2.01.00: The 1850 to 2 Angstrom Wavelength Region

Spectroscopy of the electromagnetic spectrum in the region between 1850 and 2 Angstroms requires special techniques not required for the visible portion of the spectrum. In general, the need for special techniques stems from the opacity of most common substances to radiation in this region. Included in the list of opaque materials are such normal spectrograph constituents as glass lenses, prisms, photographic emulsion gelatine and the common atmospheric gases.

2.02.00: The Opacity of Air

Air is almost entirely opaque to radiation in the 1850 to 2 Angstrom region of the electromagnetic spectrum.[1] The long wave length opacity limit is established by oxygen which becomes opaque beyond approximately 1850 Angstroms except for some regions of weak absorption between 1000 and 1250 Angstroms.[2] Nitrogen exhibits a series of narrow absorption bands between 1450 and 990 Angstroms, becoming completely opaque below 990 Angstroms.[3] Other atmospheric constituents also absorb radiation in this

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(1) Boyce, J. C., Spectroscopy of the Vacuum Ultraviolet. Rev. Mod. Phys., Vol. 13, p.2, Jan. 1941.

(2) Ibid. pp. 3-4.

(3) Ibid.

same region. The atmosphere gradually becomes transparent to radiation of wavelengths shorter than approximately 2 Angstroms.(1)

2.03.00: Definition of the Vacuum Ultraviolet

The opacity of the common atmospheric gases makes it necessary to perform most experiments in the 1850 to 2 Angstrom region in an atmosphere free of the offending gases.(2) As the most practical method of fulfilling this requirement is to conduct such experiments in a vacuum, this segment of the spectrum is known as the Vacuum Ultraviolet. The vacuum ultraviolet extends to and overlaps into the soft x-ray region.(3) As the ultraviolet and soft x-ray radiations differ only in their manner of origin, they are indistinguishable. Hence, the vacuum ultraviolet may be considered to include the vacuum portion of the soft x-ray spectrum.

2.04.00: Opacity of Lenses and Prisms

As ordinary lens and prism materials are opaque in the vacuum ultraviolet region, ordinary spectrographic techniques and apparatus may not be used even in evacuated chambers. Although some possible lens and prism materials are at least semi-transparent down to approximately 1100 Å (Quartz-1450 Å, florite-1250 Å, and lithium

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(1) Ibid., p.2.

(2) Sawyer, R. A., Experimental Spectroscopy. N.Y., Prentice Hall, 1946, p. 288.

(3) Boyce, J. C., Op. cit., p. 2.

fluorite-1100 Å),[1] the difficulties involved in using these materials and their limited range constitute serious handicaps. Consequently, most present day vacuum spectrographs for use in the vacuum ultraviolet are built around diffraction gratings ruled on concave mirrors. Such concave gratings are self-focusing and hence radiation absorbing collimating lenses are not necessary. The only absorption losses are those from gases in the optical path and at the reflecting surfaces of the grating. Hence, such spectrographs can be made usable over the entire ultraviolet region of the spectrum.

2.05.00: Difficulty of Detection

The gelatine in normal photographic emulsions absorbs all radiation in the vacuum ultraviolet region. Consequently, the detection of radiation in the vacuum ultraviolet is usually more difficult than in the visible region.

2.06.00: Light Source Requirements

Although light sources for use in the vacuum ultraviolet are not very different from those used for the longer wavelengths, special techniques are again required. Because most gases and vapors are opaque to the desired radiations, it is necessary either to provide transparent gases or reduce the optical path length through the offending gas. Light sources are discussed in detail in section 3.08.00.

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(1) Boyce, Op. cit., p. 6.

2.07.00: Need for Research

Despite the difficulties involved in spectroscopy of the vacuum ultraviolet and soft x-ray regions of the spectrum, a sufficient amount of information remains locked in these regions to make research worth while.

2.08.00: Selection of Thesis Problem

2.08.01: Reasons for Selection

Previous effort had been expended by Chapin [(1)] and Chamberlain[(2)] at the Missouri School of Mines and Metallurgy toward the construction of a grazing incidence vacuum spectrograph. As a result, such an instrument had been constructed and tested. In view of the large amount of work remaining to be done in the vacuum ultraviolet and the existence of the Chapin -Chamberlain spectrograph, the continuation of this project was deemed desirable. Consequently, the author commenced work on the project in the fall of 1955.

2.08.02: Decision to Build New Instrument

A careful study of the Chaplin-Chamberlain spectrograph, and the conclusions reached by Chamberlain led to the decision to design and build an entirely new instrument using the existing grating, vacuum pumps and if possible, the plate holder. This thesis presents the new design.

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(1) Chapin , L. H., A Grazing Incidence Vacuum Spectrograph, M.S.M. unpublished masters thesis, 1950.

(2) Chamberlain, W. C. J., The Completion, Adjustment and Operation of a Vacuum Ultraviolet Spectrograph, M.S.M. unpublished masters thesis, 1951.

3.00.00: REVIEW OF LITERATURE

3.01.00: First Ultraviolet Investigation: Schumann

The earliest probes into the vacuum ultraviolet were made by Victor Schumann in 1893.[1] Using fluorite prisms and lenses and special photographic plates in a spectrograph completely enclosed in a vacuum, Schumann was able to detect radiation in the 1200 Angstrom region.[2] In order to detect radiation in the 1850 to 1200 Angstrom region (the Schumann region), Schumann developed a method of preparing the practically gelatine-free photographic plates that bear his name and are still used.

3.02.00: Introduction of the Concave Grating and the Normal Incidence Spectrograph

3.02.01: Establishment of Wave Length Standards

Short wavelength radiation absorption by the fluorite limited Schumann to wavelengths longer than 1200 Angstroms. In 1906, Theodore Lyman utilized the concave grating invented by Rowland in 1882 to extend spectroscopic measurements down to 500 Angstroms.[3] With his grating spectrograph, Lyman was able to make the first absolute wave-length measurements in the vacuum ultraviolet and consequently established the first set of wave-length standards for this spectral region.

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(1) Boyce, Op. cit., p. 3.

(2) Sawyer, Op. cit., p. 288.

(3) Ibid., p. 289.

3.02.02: Lyman's Spectrograph

Lyman's spectrograph was a 50 cm normal incidence unit enclosed in a 91 mm brass tube. A complete description of this instrument is given in Lyman's "Spectroscopy of the Extreme Ultraviolet."(1) Accurate wavelength determinations were made possible by the use of a double slit arrangement with entrance slits displaced so that spectral lines differing in wavelength by 1180 Angstroms were concident on the Rowland Circle.(2) Although fluorite prism spectrographs continue to be used for work in the Schumann region, Lyman's grating spectrograph firmly established the grating in the field of vacuum spectroscopy and was the prototype of all later normal-incidence vacuum spectrographs.

3.02.03: Short Wavelength Limit of Normal Incidence Spectrographs

In 1921, Millikan introduced the hot spark light source and was able to extend spectroscopic observations to wavelengths somewhat shorter than 200 Angstroms using a normal incidence spectrograph.(3) Because of the extremely low reflectivity of grating materials at near normal incidence, the usefulness of the normal incidence spectrograph in this range is severly limited. For all practical purposes, normal incidence spectrographs will not operate at wavelengths shorter than 300 Angstroms.

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(1) Lyman, T., Spectroscopy of the Extreme Ultraviolet. N. Y., Longman's Green and Co., 1922.

(2) Sawyer, Op. cit., p. 290.

(3) Boyce, Op. cit., p. 3.

3.03.00: The Grazing Incidence Spectrograph

In 1923, A. H. Compton demonstrated that x-rays undergo total reflection when they strike a metal surface at a grazing incidence.[1] Taking advantage of this reflection, Compton used a grating at grazing incidence to measure x-ray wavelengths.[2] Shortly thereafter (1927), Osgood extended the use of the grazing incidence spectrograph to the measurement of soft x-rays. About the same time, Hoag used a grazing incidence spectrograph to close the gap between soft x-rays and the short wavelength limit of normal incidence instruments. Since that time, grazing incidence spectrographs have been used with great success in the region between zero and 1000 Angstroms.[3] Such instruments have been used to observe ultraviolet wavelengths as short as 12.1 Angstroms. (The 12.1 Angstrom line was photographed by Tyren, using an 89 degree angle of incidence.[4] A detailed discussion of grazing incidence spectrographs is given in section 3.06.00.

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(1) Sawyer, Op. cit., p. 292.

(2) Harrison, Op. cit., p. 3.

(3) Sawyer, op. cit., p. 292.

(4) Ibid., p. 293.

3.04.00: Theory of the Concave Grating

3.04.01: Derivation of Concave Grating Equation

As the concave grating is the heart of most spectrographs for use in the vacuum ultraviolet, a discussion of concave grating theory is in order. The following derivation based upon a more detailed derivation by Namioka[1] is of interest.

Consider a concave spherical surface of radius R with a plane through the center of the sphere and the center of the surface. The plane (The plane of the paper in figure 3.04.01A) intersects the surface in a circular arc. Lines are ruled on the surface perpendicular to the plane and equally spaced along the cord of the arc.

Consider a right handed coordinate system X, Y, Z such that X and Y are parallel with the plane through the center of the spherical surface and Z is perpendicular to the X, Y surface. X is defined as positive toward the center of the sphere. The point (o,o,o) is taken at the center of the spherical surface.

A point A(x,y,z) on the entrance slit, a point of observation B(x',y',z') and a point on the grating surface G(X,Y,Z) are defined. Any point G(X,Y,Z) must satisfy the equation:

$$(X-R)^2 + Y^2 + Z^2 = R^2 \qquad (3.04.01A)$$

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(1) Namioka, T. Theory of the Concave Grating. J. Opt. Soc. Am. 49, 951 (1959).

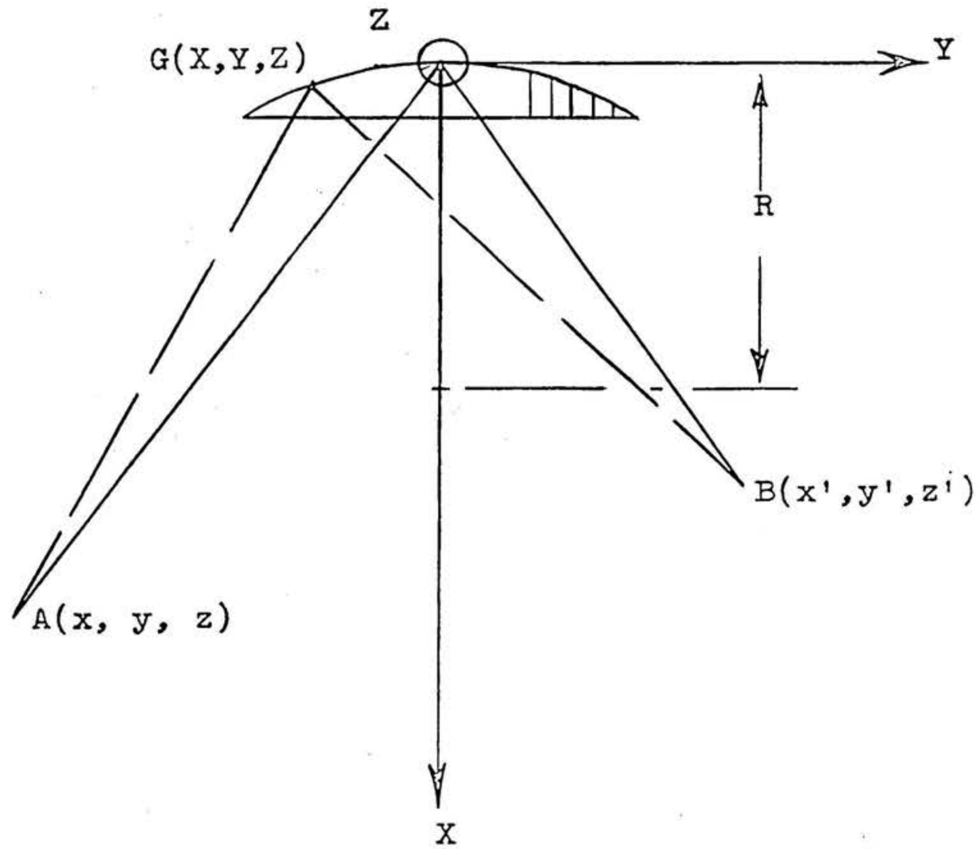

Figure 3.04.01A: Grating Coordinates

In order to determine what is observable at point B, it is necessary to discover the manner in which the various wavelets from A which strike the grating at various points (G) interfere at observations point B. The manner in which they interfere is governed by the differences in the lengths of the paths they travel from A to B. (It is assumed that the width of the lines of the grating are of infinitesimal width and that reflection occurs only from these lines.)

The lengths of the paths AG and GB are:

$$|AG| = \left[(x - X)^2 + (y - Y)^2 + (z - Z)^2 \right]^{\frac{1}{2}} \qquad (3.04.01B)$$

and

$$|GB| = \left[(x' - X)^2 + (y' - Y)^2 + (z' - Z)^2 \right]^{\frac{1}{2}} \qquad (3.04.01C)$$

Equation 3.04.01A may be rewritten as:

$$X = R \pm \left[R^2 - Y^2 - Z^2 \right]^{\frac{1}{2}}$$

Only the minus sign is physically significant. Rewriting again gives:

$$X = R \left\{ 1 - \left[1 - \frac{(Y^2 - Z^2)}{R} \right]^{\frac{1}{2}} \right\} \qquad (3.04.01D)$$

A series expansion of the term in the inner bracket in 3.04.01D gives:

$$X = R \left\{ 1 - \left[1 - \frac{(Y^2 - Z^2)}{2R} - \frac{(Y^2 - Z^2)^2}{8R} + \cdots \right] \right\}$$

or

$$X = \frac{(Y^2 - Z^2)}{2R} + \frac{(Y^2 - Z^2)^2}{8R} + \cdots \qquad (3.04.01E)$$

It is convenient to use a set of cylindrical coordinates where:

$x = r \cos\alpha$, $y = r \sin\alpha$, $x' = r'\cos\beta$ & $y' = r'\sin\beta$ and r, r', α and β are as indicated in figure 3.04.01B.

It is also important to note that Y/R and Z/R are small in comparison to unity; and that Y/r, Z/r, z/r, Y/r', Z/r' and z'/r' are small in the cases of interest.

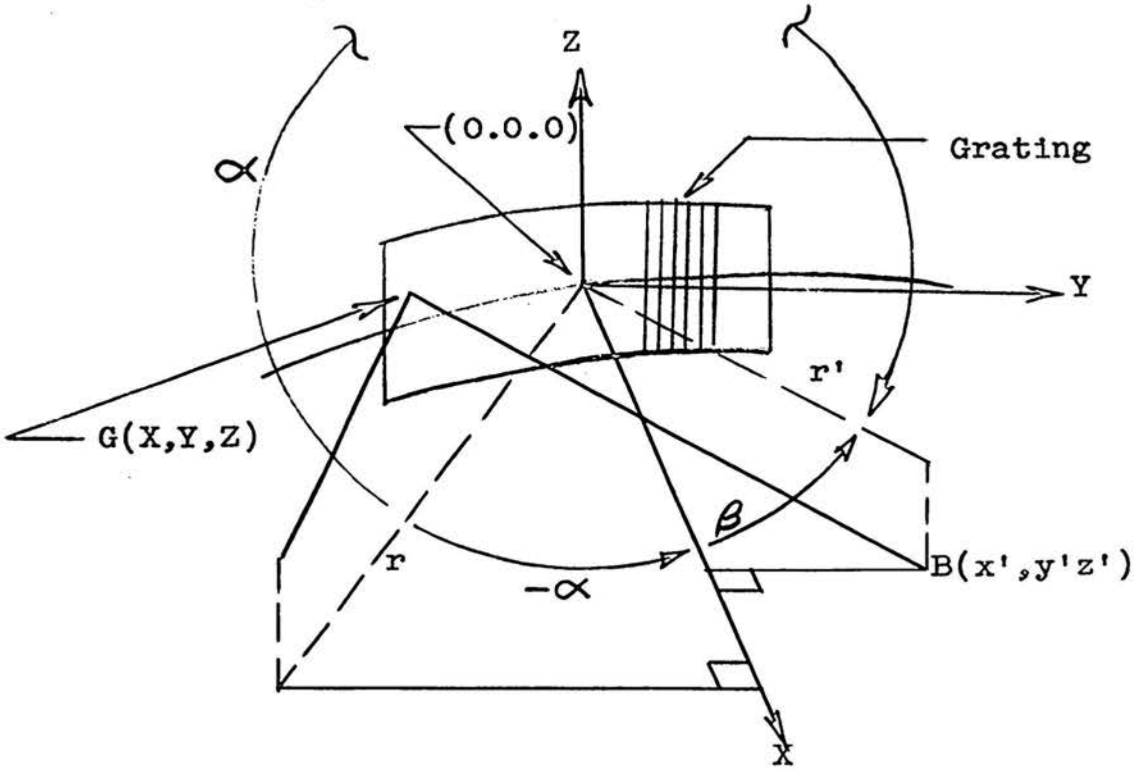

Figure 3.04.01B: Angles Used in Grating Equation

Rewriting 3.04.01B and converting to cylindrical coordinates gives:

$$|AG| = \left[r^2 + z^2 - 2rX\cos\alpha - 2rY\sin\alpha - 2zZ + (X^2 - Y^2 - Z^2)\right]^{\frac{1}{2}} \quad (3.04.01F)$$

Substituting from 3.04.01A gives:

$$|AG| = \left[r^2 + z^2 - 2rX\cos\alpha - 2rY\sin\alpha - 2zZ + 2RX\right]^{\frac{1}{2}} \quad (3.04.01G)$$

Factoring out $r(\,1 + Z^2/r^2)^{\frac{1}{2}}$ and letting $(\,1 + Z^2/r^2)$ equal Q gives:

$$|AG| = rQ^{\frac{1}{2}}\left[1 - \left(\frac{2X\cos\alpha}{rQ} + \frac{2Y\sin\alpha}{rQ} + \frac{2zZ}{r^2Q} - \frac{2RX}{r^2Q}\right)\right]^{\frac{1}{2}} \qquad (3.04.01H)$$

Expanding the 1/2 power term gives:

$$\begin{aligned}|AG| = rQ^{\frac{1}{2}}\Bigg[1 &- \frac{X\cos\alpha}{rQ} - \frac{Y\sin\alpha}{rQ} - \frac{zZ}{r^2Q} + \frac{RX}{r^2Q} - \frac{X^2\cos^2\alpha}{2r^2Q^2} \\ &- \frac{Y^2\sin^2\alpha}{2r^2Q^2} - \frac{z^2Z^2}{2r^4Q^2} - \frac{R^2X^2}{2r^4Q^2} - \frac{XY\cos\alpha\sin\alpha}{r^2Q^2} \\ &- \frac{zZX\cos\alpha}{r^3Q^2} - \frac{RX^2\cos\alpha}{r^3Q^2} - \frac{zZY\sin\alpha}{r^3Q^2} - \frac{RXY\sin\alpha}{r^3Q^2} \\ &+ \frac{RzZX}{r^4Q^2} + \cdots\Bigg]\end{aligned} \qquad (3.04.01I)$$

Clearing the brackets gives:

$$\begin{aligned}|AG| = rQ^{\frac{1}{2}} &- \frac{X\cos\alpha}{Q^{\frac{1}{2}}} - \frac{Y\sin\alpha}{Q^{\frac{1}{2}}} - \frac{zZ}{rQ^{\frac{1}{2}}} - \frac{RX}{rQ^{\frac{1}{2}}} - \frac{X^2\cos^2\alpha}{2rQ^{3/2}} \\ &- \frac{Y^2\sin^2\alpha}{2rQ^{3/2}} - \frac{z^2Z^2}{2r^3Q^{3/2}} - \frac{R^2X^2}{2r^3Q^{3/2}} - \frac{XY\cos\alpha\sin\alpha}{rQ^{3/2}} \\ &- \frac{zZX\cos\alpha}{r^2Q^{3/2}} + \frac{RX^2\cos\alpha}{r^2Q^{3/2}} - \frac{zZY\sin\alpha}{r^2Q^{3/2}} + \frac{RXY\sin\alpha}{r^2Q^{3/2}} \\ &- \frac{RzZX}{r^3Q^{3/2}} + \cdots\end{aligned} \qquad (3.04.01J)$$

At this point, it is worthwhile to examine the terms of this expression as to their magnitudes relative to R.

As an approximation, all terms of fourth and higher orders in the previously mentioned small quanitities will be discarded. Examination of X (equation 3.04.01E) reveals that all terms after the first term are of higher than third order and may be dropped. In the spirit of this approximation, the z^2/r^2 portion of the Q term will be dropped from the denominators of all terms except the third. The third term is of first order in smallness as Y is involved to the first power. All other terms involving the Q term are at least second order. As the z^2/r^2 of the Q term is second order itself, the correction it produces will be at least fourth order. Hence it will be dropped. Discarding the higher order terms, substituting for X and rewriting gives:

$$\left|AG\right| \approx rQ^{\frac{1}{2}} - \frac{Y^2\cos\alpha}{2R} - \frac{Z^2\cos\alpha}{2R} - \frac{Y\sin\alpha}{Q^{\frac{1}{2}}} - \frac{zZ}{r}$$

$$- \frac{(Y^2 - Z^2)}{2r} - \frac{Y^2\sin^2\alpha}{2r} - \frac{(Y^2 - Z^2)Y\cos\alpha\sin\alpha}{2rR}$$

$$- \frac{zZY\sin\alpha}{r^2} - \frac{(Y^2 - Z^2)\ Y\sin\alpha}{2r^2} \qquad (3.04.01K)$$

Combining terms and rewriting gives:

$$|AG| \approx rQ^{\frac{1}{2}} - \frac{Y\sin\alpha}{Q^{\frac{1}{2}}} - \frac{zZ}{r} + \frac{Y^2}{2r}\left(\cos^2\alpha - \frac{r}{R}\cos\alpha\right)$$

$$+ \frac{Z^2}{2r}\left(1 - \frac{r}{R}\cos\alpha\right) - \frac{(Y^2 - Z^2)\,Y\cos\alpha\sin\alpha}{2rR}$$

$$- \frac{zZY\sin\alpha}{r^2} - \frac{(Y^2 - Z^2)\,Y\sin\alpha}{2r^2} \qquad (3.04.01L)$$

Using equation 3.04.01C, a completely analogus function may be found for the path $|GB|$:

$$|GB| \approx r'Q'^{\frac{1}{2}} - \frac{Y\sin\beta}{Q'^{\frac{1}{2}}} - \frac{z'Z}{r'} - \frac{Y^2}{2r'}\left(\cos^2\beta - \frac{r'}{R}\cos\beta\right)$$

$$- \frac{Z^2}{2r'}\left(1 - \frac{r'}{R}\cos\beta\right) - \frac{(Y^2 - Z^2)\,Y\cos\beta\sin\beta}{2r'R}$$

$$- \frac{z'Zy\sin\beta}{r'^2} - \frac{(Y^2 - Z^2)\,Y\sin\beta}{2r'^2} \qquad (3.04.01M)$$

where $Q' = \left[\,1 - (z'/r')^2\,\right]$.

The total path length $|AGB|$ is $|GB| - |AG|$ or the sum of equations 3.04.01L and 3.04.01M. In the interest of brevity, the complete expression for the path length will not be written out.

In order that light of relatively great intensity be observed at B, each ruling of the grating should contribute a wavelet which differs in phase from the wavelets reflected by adjacent rulings by 2π, 4π, 6π, etc. so that interference is constructive. Thus, the path length of light that strikes one ruling will differ from the path length of light from an adjacent ruling by an integral number of wavelengths of the radiation observed at B.

Instead of making sure explicitly that the path lengths of wavelets from two rulings on the grating a distance d apart interfere constructively, a continuous function, $F(Y,Z)$, that can be handled by analytical means will be constructed. The function $F(Y,Z)$ is defined as:

$$F(Y,Z) = |AGB| + \frac{nY}{d}\lambda \qquad (3.04.01N)$$

where n is an integer.

For a case in which constructive interference of light from the rulings is produced at observation point B, translation of the point G from one ruling to the next (changing Y by $\pm$ d) changes the path length by an integer multiplied by the wavelength λ. By a suitable choice of n, the function $F(Y,Z)$ can be made a constant when the interference is constructive. Note that although the rulings are only at discrete values of Y, F(Y,Z) can be made a constant for all values of Y within a certain range when constructive interference takes place. The dependence on Z is unchanged from that of $|AGB|$. According to Fermat's principle, the condition that the grating operate is that:

$$\frac{\partial F}{\partial Y} = 0 = \frac{\partial F}{\partial Z} \qquad (3.04.01\ O)$$

to some approximation.

A first order approximation using only terms of zero order in relation to R gives:

$$\frac{\partial F}{\partial Y} = 0 = -\frac{\sin\alpha}{Q^{\frac{1}{2}}} - \frac{\sin\beta}{Q'^{\frac{1}{2}}} + \frac{n\lambda}{d} \qquad (3.04.01P)$$

As the Z^2/r^2 and $(z^2/r')^2$ in the Q terms are second order corrections, they may be dropped in this approximation giving:

$$0 = \frac{\partial F}{\partial Y} \approx -\sin\alpha - \sin\beta + \frac{n\lambda}{d}$$

or:

$$\sin\alpha - \sin\beta \approx \frac{n\lambda}{d} \qquad (3.04.01\ Q)$$

This is the familiar equation for both plane and spherical gratings. The discarded second order corrections in the Q terms, $(1 - z^2/r^2)^{\frac{1}{2}}$ and $(1 - [z'/r']^2)^{\frac{1}{2}}$, indicate that for straight source slits of finite length, the spectral lines formed at B will be curved images.

3.04.02: Concave Grating Mounting Theory

A second order approximation of equation 3.04.01-0 using only zero and first order terms gives:

$$0 = \frac{\partial F}{\partial Y} \approx -\sin\alpha - \sin\beta - \frac{n\lambda}{d}$$

$$- Y \left[\frac{\cos^2\alpha}{r} - \frac{\cos\alpha}{R} - \frac{\cos^2\beta}{r'} - \frac{\cos\beta}{R} \right]$$

(3.04.02A)

Equation 3.04.02A may be satisfied for all values of Y if $n\lambda = d(\sin\alpha + \sin\beta)$ and if

$$\left[\frac{\cos^2\alpha}{r} - \frac{\cos\alpha}{R} \quad \frac{\cos^2\beta}{r'} - \frac{\cos\beta}{R} \right] = 0.$$

Various grating mounting methods satisfy the latter condition in various ways. For example, a plane grating ($R = \infty$) generally has parallel radiation incident ($r = \infty$) and reflected ($r' = \infty$). Rowland Circle mountings use the choice $r = R\cos\alpha$, $r' = R\cos\beta$. The entrance slit, $A(r, \alpha)$, and the point of observation, $B(r', \beta)$, both lie on a circle of radius R/2 (the Rowland Circle) tangent to the grating at its center. A Rowland Circle mounting is used in the instrument described in this document.

3.04.03: Rowland Circle Mounting Astigmatism

Setting $\partial F/\partial Z = 0$ in accordance with equation 3.04.01-0 and discarding terms of second and higher orders gives:

$$0 = \frac{\partial F}{\partial Z} = -\frac{z}{r} - \frac{z'}{r'} + Z\left[\frac{1}{r} + \frac{1}{r'} - \frac{\cos\alpha}{R} - \frac{\cos\beta}{R}\right].$$

(3.04.03A)

For the Rowland Circle mounting conditions, $r = R\cos\alpha$ and $r' = R\cos\beta$,

$$z' = -\frac{z\cos\beta}{\cos\alpha} + Z\left[\frac{1}{\cos\alpha} + \frac{1}{\cos\beta} - \cos\alpha - \cos\beta\right]\cos\beta$$

$$z' = -\frac{z\cos\beta}{\cos\alpha} + Z\left[\frac{\sin^2\alpha}{\cos\alpha} + \frac{\sin^2\beta}{\cos\beta}\right]\cos\beta .$$

(3.04.03B)

From a point on the entrance slit, $z = 0$, a line of points of observation z' will be found for which constructive interference will be observed for wavelets from various heights, Z, on the grating. If the highest point on the grating is at L/2 and the lowest is at - L/2, the length of a line formed at the observation point will be:

$$l = 2\left\{\frac{L}{2}\left[\frac{\sin^2\alpha}{\cos\alpha}\cos\beta + \sin^2\beta\right]\right\}$$

or $l = L\left[\sin\alpha\tan\alpha\cos\beta + \sin^2\beta\right]$. (3.04.03C)

This is the length of the astigmatic image of a point on the entrance slit.

3.04.04: Defocusing Caused by Grating Rotation

It is of interest to examine the defocusing caused by rotating the grating about its Z axis as is frequently done in rocking grating monochromators. The Rowland mounting satisfies equation 3.04.02A by making

$$\frac{\cos^2(-\alpha)}{r} - \frac{\cos(-\alpha)}{R} + \frac{\cos^2\beta}{r'} - \frac{\cos\beta}{R} = 0 \qquad (3.04.04A)$$

For a normal incidence spectrograph, $(-\alpha)$ and β are both small and 3.04.04A may be approximated by:

$$\frac{1}{r}\left(1 - \frac{\alpha^2}{2!} + \cdots\right)^2 - \frac{1}{R}\left(1 - \frac{\alpha^2}{2!} + \cdots\right) + \frac{1}{r'}\left(1 - \frac{\beta^2}{2!} + \cdots\right)^2$$
$$- \frac{1}{R}\left(1 - \frac{\beta^2}{2!} + \cdots\right) = 0.$$

Retaining only terms of second and lower order in α and β and rewriting gives:

$$\frac{1}{R}\left[\frac{R(1-\alpha^2)}{r} - \left(1 - \frac{\alpha^2}{2}\right) + \frac{R(1-\beta^2)}{r'} - \left(1 - \frac{\beta^2}{2}\right)\right. \approx 0 \qquad (3.04.04B)$$

If the entrance and exit slits are initially on the Rowland Circle, $r = R\cos\alpha$, r may be replaced by $R\cos\alpha_o = 1 - \alpha_o^2 + \cdots$ giving:

$$\frac{(1-\alpha^2)}{(1-\alpha_o^2)} - \left(1 - \frac{\alpha^2}{2}\right) + \frac{R(1-\beta^2)}{r'} - \left(1 - \frac{\beta^2}{2}\right) \approx 0 \qquad (3.04.04C)$$

Solving for r' gives:

$$r' \approx R(1 - \beta^2)/(1 - \frac{\beta^2}{2} + \frac{\alpha^2}{2} - \alpha_o^2).$$

Expanding the lower term and retaining only the first two terms gives:

$$r' \approx R(1-\beta^2)\left(1+\frac{\beta^2-\alpha^2}{2}+\alpha_o^2+\ldots.\right).$$

Performing the indicated operations and discarding all third and higher order terms in α and β gives:

$$r' \approx R\left[1+\frac{(\beta^2-\alpha^2)}{2}+\alpha_o^2-\beta^2\right]. \qquad (3.04.04D)$$

For fixed entrance and exit slits, $-\alpha+\beta=\theta$, where θ is a fixed angle. Thus, $\alpha=\beta-\theta$. Substituting in equation 3.04.04D gives:

$$r' \approx R\left[1+\frac{\beta^2-(\beta-\theta)^2}{2}+\alpha_o^2-\beta^2\right] \qquad (3.04.04E)$$

Taking the derivative of r' with respect to β gives:

$$dr' \approx R(\theta-2\beta)\,d\beta. \qquad (3.04.04F)$$

It is interesting to note that for the case $\beta=\theta/2$, the defocusing is zero to this order of approximation.

3.05.00: Development of the Normal Incidence Spectrograph

3.05.01: Typical N-I Spectrograph Arrangement

A considerable number of normal incidence spectrographs have been constructed. A typical arrangement for such instruments is shown in figure 3.05.01A.

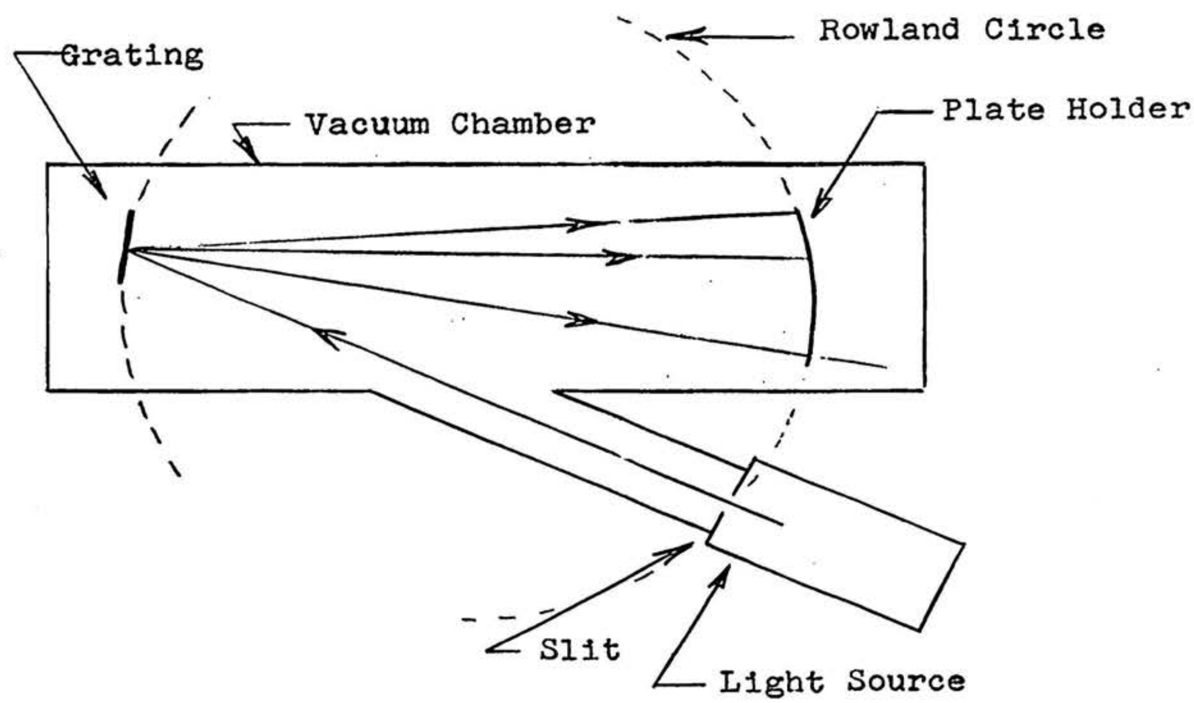

Figure 3.05.01A: Typical Normal Incidence Vacuum Spectrograph Arrangement

Such spectrographs have ranged in size from small units such as the one used by Lyman (50 cm) up to a 21 foot unit constructed by Harrison in 1933. Descriptions of a number of such units are available in the literature.

3.05.02: Compton and Boyce Two Meter Spectrograph

A typical two meter spectrograph covering the range from zero up to 2500 Angstroms (first order spectra) was built by Compton and Boyce in 1921 around a 30,000 line per inch glass grating.[1] This instrument gave a dispersion of approximately 4.27 Angstroms/mm. and recorded strong spectra at wavelengths as short as 300 Angstroms with some 200 Angstrom lines on long exposures.

3.05.03: Sawyer's One Meter Spectrograph

Another typical spectrograph is described in Sawyer's "Experimental Spectroscopy."[2] This spectrograph was built around a one meter, 15,000 line per inch grating which gave a dispersion of 17 Angstroms/mm. and gave coverage to 3000 Angstroms on the same plate in one exposure. The grating mount provided focusing motion as well as rotation about all three axes of the grating.

3.05.04: A Twenty-one Foot Normal Incidence Spectrograph

Probably the largest vacuum spectrograph constructed was a 21 foot instrument described by Harrison.[3] A 15,000 line per inch grating was used at first, but later work was done using 30,000 line per inch glass and

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(1) Compton, K. T., and Boyce, J. C. A Broad Range Vacuum Spectrograph for the Extreme Ultraviolet. Rev. Sci. Inst., Vol. 5, p. 218, (June 1934).

(2) Sawyer, Op. cit., p. 290.

(3) Harrison, C. R., Improvements in the Twenty-one Foot Normal Incidence Vacuum Spectrograph. Rev. Sci. Inst. Vol. 4, p. 651, (Dec. 1933)

speculum metal gratings. This spectrograph covered the spectral range from 300 to 6000 Angstroms. Spectral orders up to the sixth were photographed with dispersions ranging between 2.72 and 0.22 Angstroms/mm. with the advantages of an almost normal spectrum. Wavelength measurement accuracies in the neighborhood of $\pm$ 0.005 Angstrom were possible.

3.05.05: Moving Grating Spectrographs

For many purposes, it is desirable to bring separately radiation of different wavelengths to focus upon a given point at different times by scanning the spectrum. Two instruments for accomplishing this task without moving the detection apparatus are indicated by Weissler[1] in the section dealing with the photoionization of gases in the Encyclopedia of Physics.

3.05.06: Displaced Grating Vacuum Monochromator

One method of scanning used by Tousey, Johnson, Richardson and Toran (1951) was to displace the grating along the Rowland Circle as indicated in figure 3.05.06A.[2] Such motion varied the angles of incidence and thus the spectral line image formed at the exit slit. Because the grating always remains tangent to the Rowland Circle in this arrangement, the lines at the exit slit are always in

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(1) Weissler, G. L. "Photoionization in Gases," Encyclopedia of Physics, Vol. 21, Berlin, Springer-Verlag, 1956, pp. 316-317.

(2) Ibid.

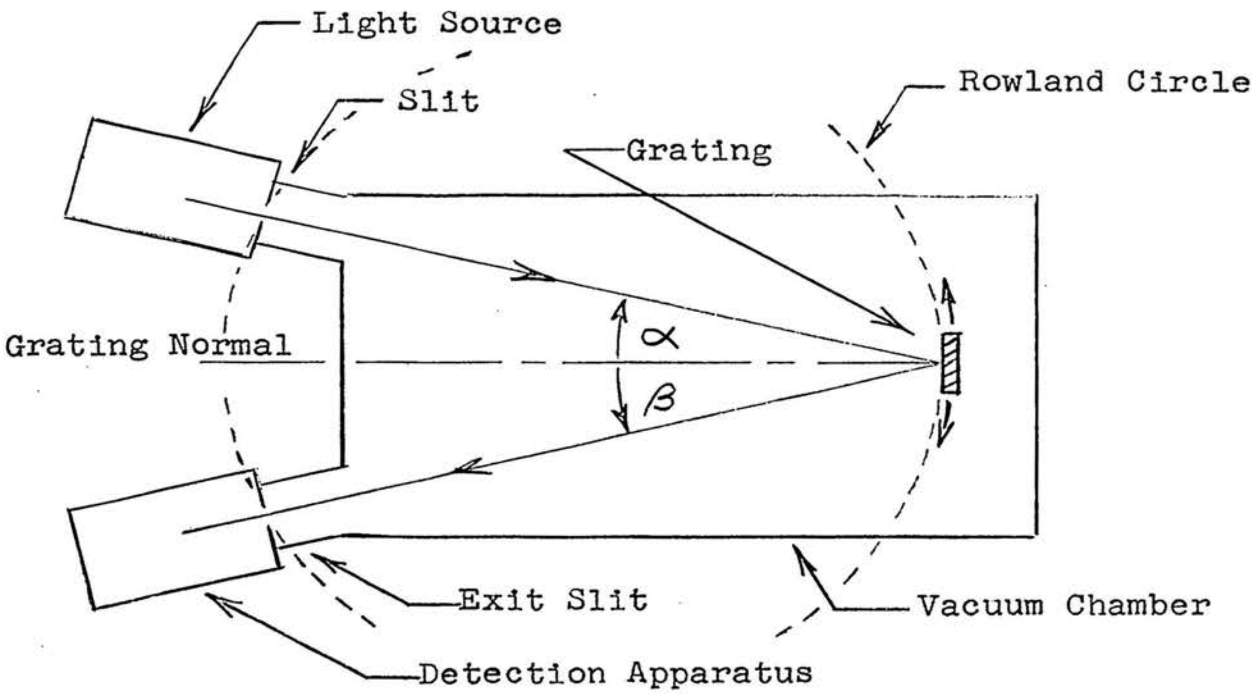

Figure 3.05.06A: Displaced Grating Monochromator: Grating is moved along Rowland Circle as indicated by arrows to vary angle of incidences and reflection, alpha and beta.

exact focus. This arrangement suffers from the disadvantage that it is difficult to keep the light source and slit sufficiently aligned to illuminate the grating properly.

3.05.07: Rocking Grating Monochromator

Another method of spectrum scanning across a fixed slit is the method used by Weissler [1] for photoionization studies in gases. In the monochromator described, the scanning was accomplished by rocking the grating about its own vertical axis as shown in figure 3.05.07A.

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(1) Ibid.

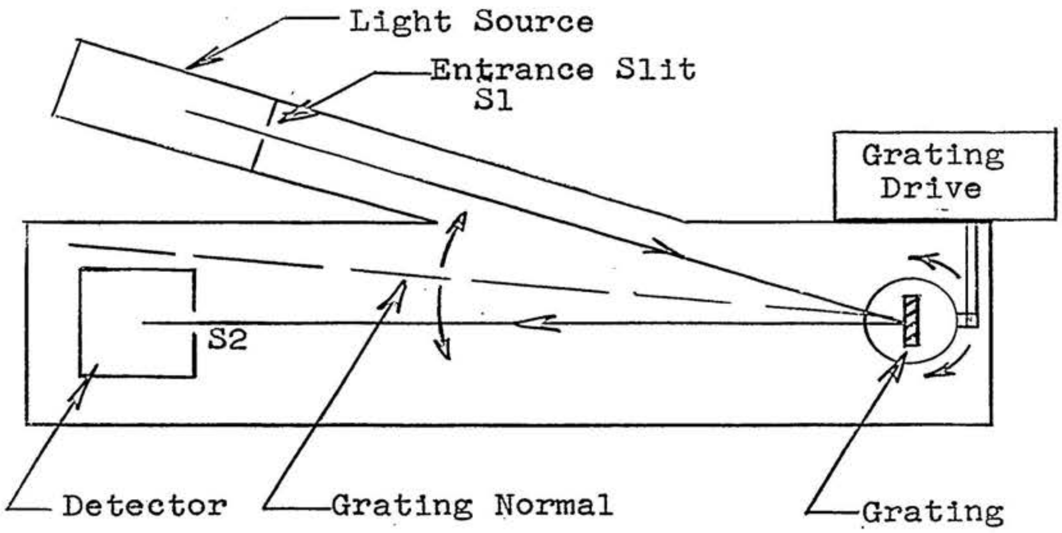

Figure 3.05.07A: Rocking Grating Monochrometer: Scanning is accomplished by rotating grating so as to move grating normal as indicated by arrows.

While rocking the grating is easier to accomplish than the displacement discussed in 3.05.06, exact focus is sacrificed. As the grating normal moves, the Rowland Circle moves with it. Consequently, the source and exit slits are exactly on this circle for only one setting of the grating. For other settings, some defocusing occurs, the degree depending upon the grating normal displacement.

3.06.00: Development of the Grazing Incidence Spectrograph

3.06.01: Grazing Incidence Arrangement

Extensive use has been made of grazing incidence spectrographs. The basic arrangement of such instruments is shown in figure 3.06.01A. Such instruments have ranged in size from a considerable number of one to one-and-one-half meter units to a colossal 21 foot focal length instrument constructed at the University of Illinois.

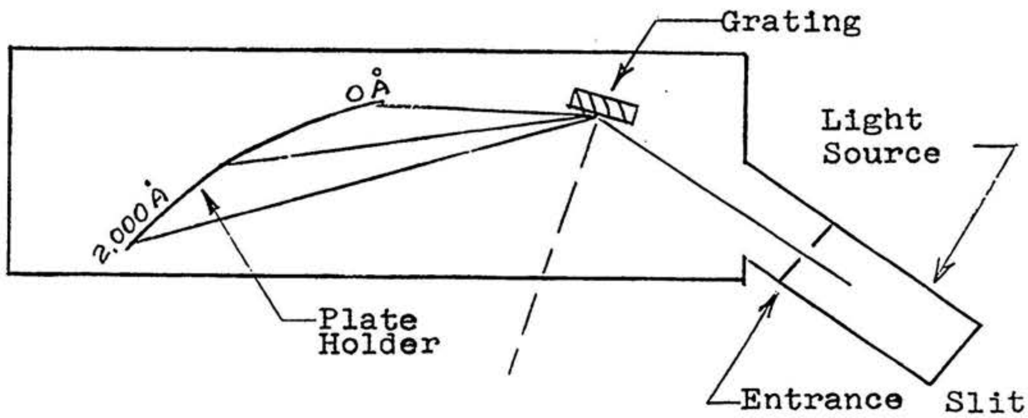

Figure 3.06.01A: Arrangement of a Grazing Incidence Spectrograph Covering the Range Zero to 2,000 Angstroms.

3.06.02: Development by Siegbahn

Extensive development of the grazing incidence spectrograph was done by Siegbahn and associates during the 1930s. Boyce [(1)] mentioned one, one-meter and two, five-meter instruments of particular significance. The earlier, one meter spectrograph, built around a 571 line/mm grating and using an 80 degree incidence angle, was effective down to 75 Angstroms. One of the later

(1) Boyce, Op.cit., p. 13.

five meter instruments used a 37,440 line, 576 line/mm grating at an 86 degree incidence angle for effective coverage of the region between 40 and 200 Angstroms.

3.06.03: Twenty-one Foot Grazing Incidence Spectrograph

A twenty-one foot grazing incidence spectrograph built by Kruger(1) in 1932 warrants mention from sheer size alone. This instrument was constructed to enable resolution of the lines observed with, but not resolved by smaller spectrographs. With a 79 degree incidence angle, resolution ranged from 0.33 Angstroms/mm at 100 Angstroms to 0.516 Angstroms/mm at 500 Angstroms.

3.06.04: Grazing Incidence in Soft X-Ray Spectroscopy

During the last two decades, the grazing incidence, concave grating spectrograph has become one of the most important tools in the study of soft x-rays. The development of methods for producing gratings with very light rulings which are free from shadow casting debris has made possible the construction of satisfactory spectrographs having incidence angles of only a few minutes. Such instruments are especially useful for work with very short wavelength ultraviolet and soft x-ray radiations. A good example is an instrument described by Sandström.(2) This spectrograph makes possible direct

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(1) Kruger, P. G. A Large Grazing Incidence Spectrograph. Rev. Sci. Inst., Vol. 4, p. 128, (March 1933)

(2) Sandstrom, A. E. "Experimental Methods of X-Ray Spectroscopy," Encyclopedia of Physics, Vol. 30, Berlin, Springer-Verlag, 1957. p. 129

comparison of lines in the extreme ultraviolet with soft x-ray lines.

3.06.05: Grazing Incidence Spectrograph for Absorption Cross Section Determination

Weissler(1) has described the use of a grazing incidence spectrograph for the determination of absorption cross sections of gases.

3.07.00: Grazing Incidence Versus Normal Incidence

3.07.01: The Two Basic Types of Vacuum Spectrographs

Both of the two basic types of vacuum spectrographs for use in the vacuum ultraviolet, normal and grazing incidence spectrographs, have their own inherent advantages. Consequently, the type selected by a designer is usually dictated by the particular use to be made of the instrument. Normal incidence spectrographs are favored in the Schumann region because their dispersion is more nearly linear and their low astigmatism gives good economy of light.(2) Normal incidence instruments are generally less critical to focus and are more useful for precise determination of wavelengths. Although normal incidence units have been used to below 300 Angstroms, the greater efficiency of gratings at grazing incidence favors the use of grazing incidence spectrographs below 600 Angstroms.(3) (The reflectivity is

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(1) Weissler, Op. cit., p. 315.

(2) Boyce, Op. cit., p. 14.

(3) Ibid.

sufficiently greater at the shorter wavelengths to overcome the handicap of light lost as a result of the greater astigmatism of gratings at grazing incidence.) Grazing incidence instruments are of greatest use in the zero to 1200 Angstrom region. The high efficiency of the grating at grazing incidence results in greater line intensities in this region; consequently, such instruments are useful for the observation of faint lines.

3.07.02: Normal Incidence Spectrograph Theory

The basic geometry of the normal incidence spectrograph is indicated by figure 3.07.02A.

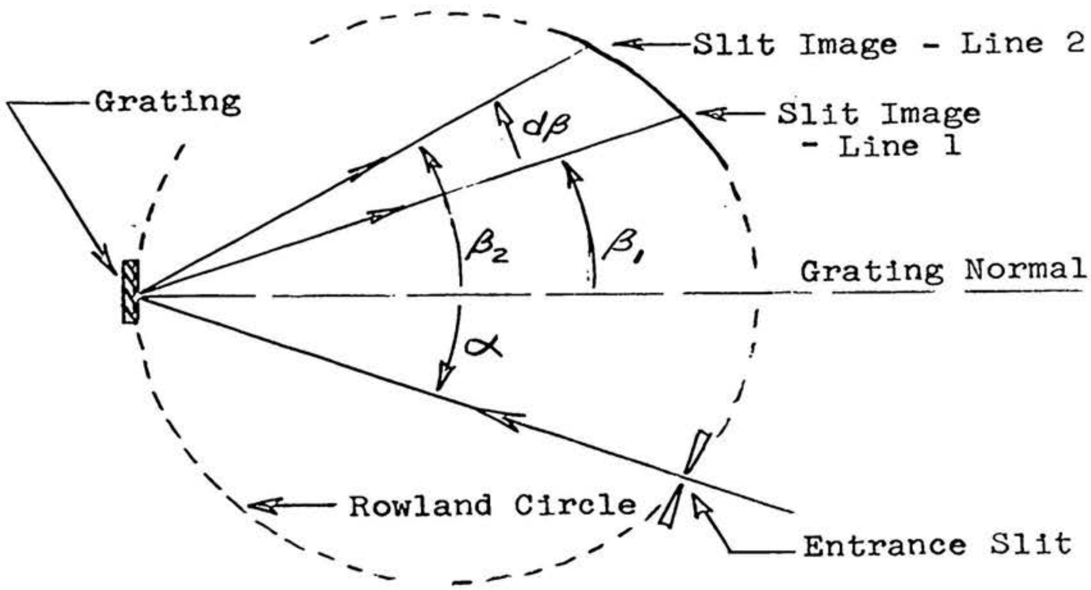

Figure 3.07.02A: Normal Incidence Geometry: Angles are defined as positive in the directions of the arrows.

Image locations in such instruments are defined by the conventional grating equation,

$$\pm n\lambda = d(\sin\alpha - \sin\beta) \qquad (3.07.02A)$$

where

$n = \pm 1, 2, 3, \ldots,$
λ = wavelength of a spectral line,
d = the grating constant (distance between rulings on the grating),
α = the angle of incidence as defined by fig. 3.07.02,
β = the angle of diffraction as defined by fig. 3.07.02

and where the images are formed on the locus of a circle (The Rowland Circle) having a diameter equal to the radius of curvature of and tangent to the surface of the grating. The basic theory of concave gratings and proof that the images fall on the Rowland Circle have been covered previously and need not be repeated here.

The linear dispersion along the Rowland Circle is given by the expression[1]

$$\frac{ds}{d\lambda} = \frac{nR}{d\cos\beta} \qquad (3.07.02B)$$

where R equals the radius of the Rowland Cirlce, d is the grating constant, n is the order and β the angle of diffraction. This equation indicates that the linear dispersion varies inversely as the cosine of the angle of diffraction (β) for any given grating. As β is usually

(1) Sawyer, Op. cit., p. 135.

small in normal incidence spectrographs, the linear dispersion is nearly constant over the useful spectral range. This feature, in addition to the fact that it is easy to determine accurately the diffraction angle[1] for an observed line makes the normal incidence spectrograph especially useful for precise wavelength determination.

From equation 3.04.03C, the image of a point on the entrance slit forms a line image of length,

$$l = L(\sin^2\beta + \sin\alpha\tan\alpha\cos\beta) \qquad (3.04.03C)$$

where L is the length of the ruled lines on the grating. Equation 3.04.03C indicates that the astigmatism is small for the small angles of incidence and diffraction used in normal incidence spectrographs. Consequently, light economy is high in such instruments.

As the grating to image distance is large and the radiation strikes the Rowland Circle almost normally, focus of normal incidence spectrographs is not critical. Consequently, the effect of minor departures of the film plate from the Rowland Circle is slight. The non-critical focus of such instruments makes them adaptable to rocking grating arrangements such as that described in section 3.05.07.

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(1) Boyce, Op. cit., p. 14.

3.07.03: Grazing Incidence Spectrograph Theory

Spectrographs for use in the extreme vacuum ultraviolet and soft x-ray regions are of the grazing incidence variety. For these wavelengths, it is necessary to utilize the high reflectivities possible at near grazing incidence in order to obtain images of adequate intensity. The basic geometry of the grazing incidence spectrograph is indicated by figure 3.07.03A.

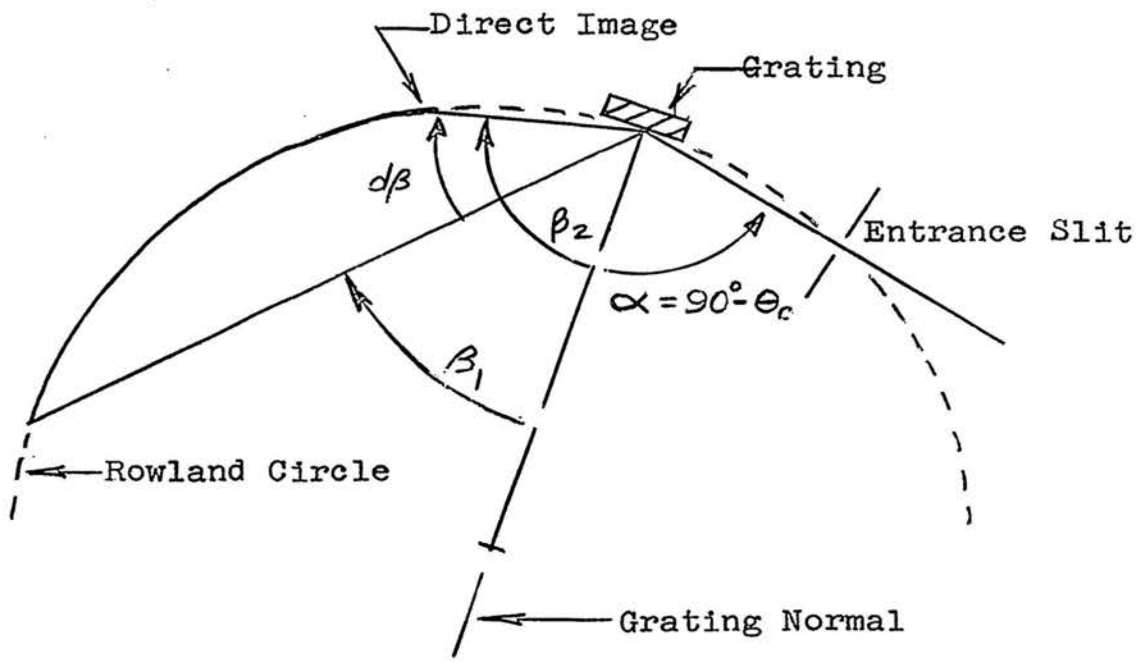

Figure 3.07.03A: Grazing Incidence Geometry: Angles are defined as positive in the direction of the arrows.

As in the case of normal incidence, the image locations on the Rowland Circle are defined by the conventional grating equation (equation 3.07.02A).

It is desirable to use an angle of incidence no greater than that necessary to obtain total reflection of the shortest wavelength, this angle is determined from the critical angle formula,[1]

$$\sin\theta_c = \frac{e\lambda}{c}\sqrt{\frac{N}{\pi m}} \qquad (3.07.03A)$$

where θ_c = the critical angle for the wavelength λ,
e = the charge of an electron,
c = the velocity of light,
m = the mass of an electron
and N = the number of electrons per unit volume.

Equation 3.07.02B indicates that as the angle of diffraction becomes large, the linear dispersion also becomes large. Because the cosine of β changes rapidly with β for the angles involved in grazing incidence spectrographs, the linear dispersion varies considerably over the range of such instruments.

Examination of equation 3.04.03C reveals that for the angles of incidence used in grazing incidence spectrographs, the astigmatism is large. This astigmatism can be used to advantage by using a moving shutter to allow a number of exposures on the same plate. On the other hand, astigmatism at grazing incidence makes necessary very accurate parallel alignment of the entrance slit and grating rulings.[2]

Examination of figure 3.07.03 disclosed that the optical paths in a grazing incidence spectrograph are much shorter than in an equivalent normal incidence instrument.

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(1) Sawyer, Op. cit., p. 292.

(2) Ibid, p. 293.

Hence, vacuum requirements are not as demanding as in the case of the normal incidence spectrograph.

Grazing incidence spectrographs are more difficult to adjust than normal incidence instruments.[1] Focusing adjustments are critical because even small errors produce noticeable displacements in line positions. It is essential that the photographic plate be formed exactly to the Rowland Circle. Although some preliminary adjustments may be made in air, final adjustments must be made upon the basis of vacuum exposures.

3.08.00: Radiation Sources

3.08.01: Vacuum Ultraviolet Sources

The problem of providing a source of radiation for the vacuum ultraviolet is complicated by the opacity of most window materials and gases. Sources must not only be capable of producing the desired radiation, but must be able to operate in either a vacuum or at very low pressures. Sawyer[2] lists four types of light sources that are useful in the vacuum ultraviolet. These are (a) arc or spark discharges in transparent gases, (b) electrodeless gas or vapor discharges, (c) hollow cathode discharges and (d) vacuum spark discharges. The first three are considered satisfactory for study of the spectra of two or three times ionized atoms. For radiation below 500 Angstroms, little

(1) Ibid., p. 293.

(2) Ibid., p. 295.

radiation is emitted by any source except the vacuum spark. Such sparks have been used to observe the highest order spectral radiation observed. Boyce [1] has provided a good survey of the available light sources and discussed the various sources mentioned above at some length. In recent work, Weissler[2] has made use of a glow discharge of the order of one ampere through hydrogen passed through a water cooled glass tube 15 cm long and 5 mm in diameter to produce what is described as an intense, many lines spectrum above 1000 Angstroms. For spectra between 1000 and 150 Angstroms, Weissler has found that a low pressure spark through a ceramic capillary of high melting point seems best.

3.08.02: Soft X-ray Sources

Most radiation sources for soft x-rays are basically the same as ordinary x-ray sources. However, special precautions are necessary in order to meet the high vacuum requirements. As window materials absorb soft x-ray radiation, the target must be inside the spectrograph vacuum chamber. As even traces of impurities on the target can materially reduce the intensity of the desired radiation, special precautions such as vacuum evaporation of the target material on the target are necessary.

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(1) Boyce, Op. cit., p. 15-20.

(2) Weissler, Op. cit., p. 319.

Tomboulian [1] and Sandstrom[2] have discussed the problem of soft x-ray source construction in some detail.

3.09.00: Detection of Ultraviolet Radiation

Although the silver salt crystals found in common photographic emulsions are sensitive to radiation in the vacuum ultraviolet, the gelatine normally used to support these crystals is opaque for wavelengths shorter than 2265 Ansgtroms.[1] Consequently, special means of detection are required in vacuum ultraviolet spectroscopy. The methods employed fall into the following general categories: Elimination or reduction of the opaque gelatine; sensitization of ordinary plates by fluorescent coatings or utilization of non-photographic techniques such as photoelectric or thermoelectric detectors. One of the earliest and most popular detectors is the Schumann plate. This plate uses a silver bromide emulsion containing only a minimum of gelatine. Ordinary photographic plates that have been specially sensitized by coating with a fluorescent oil are widely used. As most metals yield photoelectrons in this region, it is possible to use metallic detectors that are totally insensitive to radiation of longer wavelengths.[2] Ordinary photomultiplier tubes coated with fluorescent materials have also been used.[3] Very sensitive thermo-

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(1) Boyce, Op. cit., p. 8.

(2) Ibid., p. 10.

(3) Weissler, Op. cit., p. 319.

piles have been used by a number of experimeters.

3.10.00: Vacuum Ultraviolet and Soft X-Ray Research

3.10.01: Extent of Research

Vacuum ultraviolet and soft x-ray spectroscopy have played important roles in a wide range of research. Initial observations of such radiation were made in order to study the electronic structure of atoms and molecules. A large amount of work has been accomplished in the analysis of both atomic and molecular spectra. Considerable attention has been devoted to the photoelectric effects of radiations in this region. In recent years, spectroscopy of the vacuum ultraviolet has been of great value in the interpretation of astrophysical spectra. In conjunction with upper atmosphere studies, the absorption of radiation by photodissociation and photoionization of gases has recently received increasing attention. Since 1946, several high altitude research rocket flights have been devoted to the investigation of ultraviolet solar spectra and its effect upon the earth's atmosphere.

3.10.02: Atomic Ultraviolet Emission Spectra

The initial studies of vacuum ultraviolet spectra were made in order to gain knowledge of energy states not accessible from analysis of longer wavelengths. Boyce[1] estimates that important data lie in the vacuum ultraviolet for the first spectra of about 50 percent of the elements,

(1) Boyce, Op. cit., p. 2.

for the second spectra of about 85 percent of the elements and for the higher order spectra of all elements. Although vacuum ultraviolet spectra have been observed, Boyce contends that most of the early work must be regarded as survey work only and needs to be repeated with improved and more accurate equipment.

3.10.03: Molecular Ultraviolet Emission Spectra

Such important molecules as those of oxygen and nitrogen produce significant emission spectra in the vacuum ultraviolet. Observations of vacuum ultraviolet spectra have yielded important information regarding the electronic structure of such molecules. Information of this nature has been of particular interest in recent years in the study of the upper atmosphere.

3.10.04: Solid State Spectroscopy

The effects of radiation in the vacuum ultraviolet and soft x-ray regions upon certain solids are of great importance in the study of photoelectric emission and related effects. Consequently, spectroscopic investigations in these regions have yielded important information as to the electronic structure of those solids studies. In addition to photoelectric effects, the electromagnetic emission and absorption of solids have been studies, especially in the soft x-ray field. Tomboulian[1] has presented an excellent discussion of soft x-ray studies

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(1) Tomboulian, Op. cit.

along these lines both from the theoretical and experimental standpoints. Photoelectric emission has been studied extensively for many years and a considerable amount of work is currently in progress in this field. One of the most notable outcomes of this study was the formulation of the quantum theory of radiation. An excellent survey of past and current work in the study of photoelectric effects has been provided by G. L. Weissler.(1) In his paper, Weissler has outlined areas of interest in which additional work is desirable.

3.10.05: Vacuum Ultraviolet in the Upper Atmosphere

Much of the recent vacuum ultraviolet research has been stimulated by increased interest in conditions at high altitudes and in outer space. The ultraviolet spectrum of the sun has profound effects upon the earth's atmosphere, causing formation of the ionospheric layers vital to radio communications, formation of ozone, photochemical dissociation of gas molecules and other atmospheric phenomena. These solar radiations affect the atmosphere by being absorbed by it, radiations below 2900 Angstroms being totally absorbed.(2) Consequently, the earthbound physicist is left to speculate as to the initial intensities, the heights at which they are absorbed and the actual processes involved. Two avenues of investigation are open: the

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(1) Weissler, Op. cit., p. 342-382.

(2) Newell, H. E. High Altitude Rocket Research. N. Y., Academic Press, 1953. p. 149.

desired investigations may be carried out in the upper atmosphere by transporting apparatus or apparatus and men to the fringes of space by rockets or satellites; the investigations may be done in earthbound laboratories through the use of vacuum spectrographs in which the high altitude conditions may be simulated.

3.10.06: Rocket Exploration of the Upper Atmosphere

The development of high altitude rockets provided the first effective means for studying solar radiation in the upper atmosphere. Following World War II, the U.S. Naval Research Laboratory was able to fire sixty-six German V-2 rockets as well as some later American built rockets for the purpose of upper atmospheric research. Ultraviolet spectroscopy of the solar spectrum in the range between zero and 2900 Angstroms was a major project. On 10 October 1946, this V-2 rocket program provided the first extension of solar spectroscopy below the 2900 Angstrom atmospheric cutoff.(1) Subsequent flights provided normal incidence spectrograms showing the 1216 Angstrom Lyman Alpha line of hydrogen, measurement of the vertical distribution of ozone and non-spectrographic measurements of radiation down to 8 Angstroms.(2) The latter measurements were made by use of photographic plates and photon counters. The types of

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(1) Ibid., p. 150.

(2) Burgess, Eric. Frontier to Space, N.Y., Macmillian, 1954. pp. 103-120.

equipment used and the results of these rocket experiments have been discussed in considerable detail by Burgess[1] and Newell.[2] These books also discuss the composition of the upper atmosphere and the processes of photoionization and dissociation by ultraviolet radiation at high altitudes. Additional and more extensive discussions of the upper atmosphere have been provided by Boyd and Seaton,[3] Zelikoff[4] and Mitra.[5]

3.10.07: Molecular and Atomic Absorption

Radiations in the ultraviolet and soft x-ray segments of the spectrum have pronounced effect upon most gases. Absorption of such radiations by gases may produce a variety of effects. Molecules may dissociate into free atoms. A good example is molecular oxygen which, in the process of absorbing 1470 Angstrom ultraviolet radiation, dissociates into free atomic oxygen. Absorption of radiation by an atom may cause ionization. For example, atomic oxygen may be ionized by 700 Angstrom radiation. The absorption of radiation by gases plays an important role in electrical discharges in gases and upper atmospheric phenomena.

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(1) Ibid.

(2) Newell, Op. cit.

(3) Boyd, R.L.F. and Seaton, M.J. (Editors) Rocket Exploration of the Upper Atmosphere. (Collection of papers). N.Y., Interscience, 1954.

(4) Zelikoff, M. (Editor), The Threshold of Space. N.Y., Pergamon Press, 1957.

(5) Mitra, S. K. The Upper Atmosphere. Calcutta, Royal Asiatic Society for Bengal, 1952.

Extensive research in this area has been done by Weissler and associates during recent years. Weissler[1] has supplied a comprehensive summary of this field, including discussions of the extent and value of work accomplished to date, experimental techniques employed in the measurement of absorption cross sections and other desired quantities and an outline of additional research needed.

3.11.00: Vacuum Requirements

Good vacuum systems with high pumping speeds are required for vacuum ultraviolet spectrographs. Pressures on the order of 10^{-4} to 10^{-5} mmHg must be sustained, often in the presence of deliberate leaks into the system from light sources and gas absorption cells. The general techniques for obtaining such vacuums have been covered in detail by Strong,[2] Guthrie and Wakerling[3] and others and need not be repeated here. In addition to the usual precautions, Boyce[4] recommends that a valve be provided for isolating the light source from the spectrograph proper. Separate vacuum systems are usually used in conjunction with the vacuum spectrograph light sources.

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(1) Weissler, Op. cit., pp. 304-342.

(2) Strong, John, Procedures in Experimental Physics. N.Y., Prentice Hall, 1946. pp. 93-150.

(3) Guthrie, H., and Wakerling, R. K. Vacuum Equipment and Techniques. N.Y., McGraw-Hill, 1949.

(4) Boyce, Op. cit., pp. 14-15.

4.00.00: DESIGN OF THE SPECTROGRAPH

4.01.00: Design Requirements

A versatile spectrograph for use throughout the entire vacuum ultraviolet and soft x-ray ranges was desired. As the construction of such an instrument would be expensive, it was important that it be sufficiently flexible and durable to allow effective utilization for a wide variety of work over a period of many years. Rapid convertibility from one experiment to the next and the ability to accommodate separate projects on a time sharing basis were deemed desirable. It was also desirable to utilize as much of the Chaplin[1] spectrograph as possible, especially the grating and film holder. Good accuracy, mechanical stability, convenience of operation and a leak free vacuum system with adequate pumping speed to obtain and maintain the required vacuums in a short time and in the presence of gas entering from the light source were considered essential. These were the general requirements that this spectrograph was designed to fulfill.

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(1) Chaplin, Op. cit.

4.02.00: The Grating Used

4.02.01: Source and Selection of Grating

A concave grating was available from the Chaplin[(1)] spectrograph. Use of this grating by Chamberlain[(2)] had indicated that it had good brightness and would be satisfactory for use in the new instrument. The cost factor and the desire to utilize the plate holder from the previous instrument dictated the use of this grating.

4.02.02: Grating Characteristics

The grating used in this instrument was ruled on a concave speculum metal blank and aluminized after ruling.[(3)] Other characteristics[(4)] were as follows:

Diameter	2.5 inches*
Length of Ruled Lines	1 inch
Width of Ruled Area	2 inches
No. of Rulings/inch	22,240
Grating Constant	$1,141 \times 10^{-4}$ Å**
Radius of Curvature	1.5 meters

* measured by author

** computed by author and verified by Chamberlain's thesis. Chaplin gave no. of rulings per inch as 22,240 and the grating constant as 4.545×10^{-5} inches or 1.788×10^{-4} cm. The latter number does not agree with either of the other numbers or with Chamberlain's thesis. Hence, it was assumed to be in error.

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(1) Ibid.

(2) Chamberlain, Op. cit.

(3) Chaplin, Op. cit., p. 12.

(4) Ibid.

4.03.00: Normal - Grazing Incidence Combination

4.03.01: Feasibility of Combination

A study of normal and grazing incidence requirements revealed that it would be feasible to construct a single instrument with both capabilities. Such an instrument would offer the experimenter the choice of the best spectrograph type for any given need and give complete coverage of the entire vacuum ultraviolet spectrum. Furthermore, a considerable saving over the cost of separate spectrographs would result because the same grating, grating mount and vacuum system could be used in both applications. The study indicated that little compromise would be required on the part of either provision and that the cost of including both over that of a conventional normal incidence spectrograph would be negligible.

4.03.02: Grating Mount Conversion

Two possible arrangements were considered for the grazing-normal incidence combination. Both allowed the use of a common grating mount that required only rotation about the grating vertical axis to switch from normal to grazing incidence. It was believed that a sufficiently accurate indexing device could be designed to allow such conversions without any other grating adjustments.

4.03.03: Possible Arrangement Number One

One of the possible arrangements for inclusion of both normal and grazing incidence provisions is indicated by figure 4.03.03A.

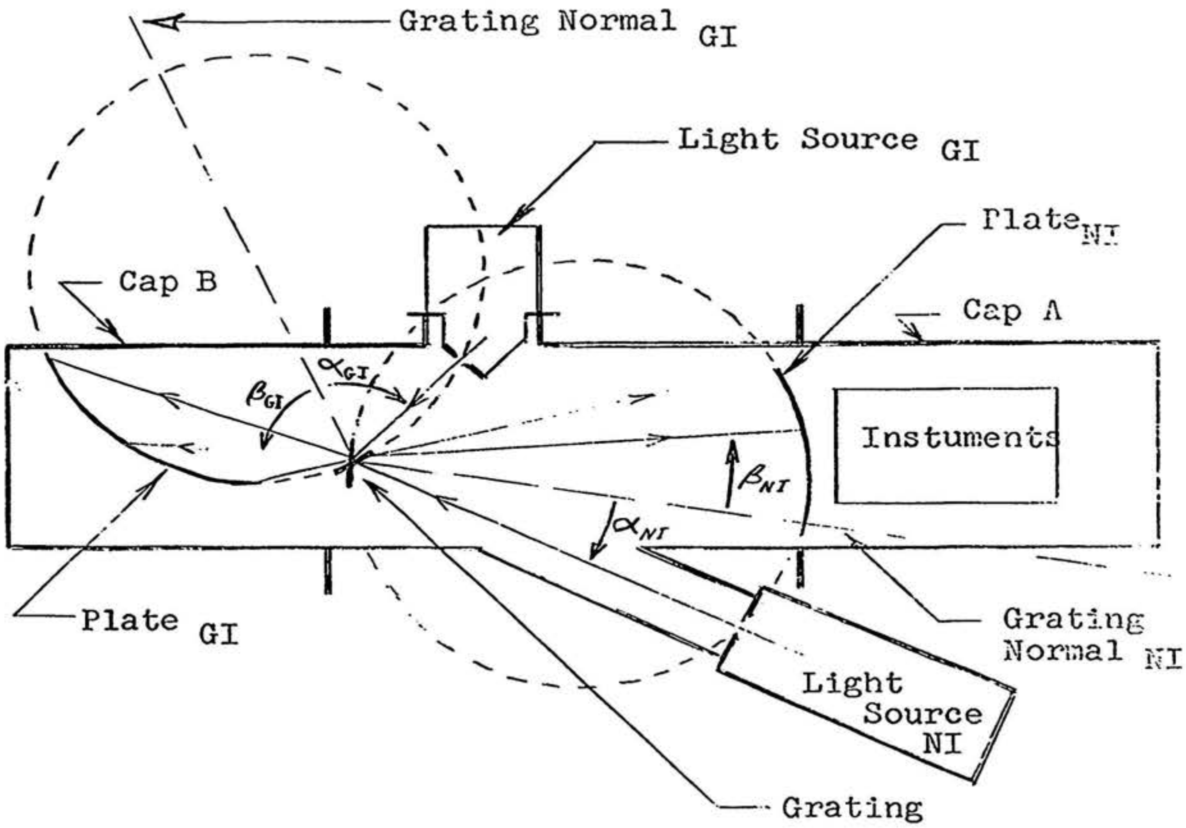

Figure 4.03.03A: Possible Arrangement for Combined Normal and Grazing Incidence

With this arrangement, conversion from normal incidence to grazing incidence could be made by merely rotating the grating as incicated. With proper design, such conversions could be accomplished quickly and without any adjustments except for rotating the grating. Adjustments of either plate holder would not be affected by use of the other provision. The plate holders and light sources for both normal and grazing incidence could remain in the instrument at all times. The entire grazing incidence plate holder would be accessible after the removal of cap B.

The arrangement shown in figure 4.03.03 would have some serious disadvantages. Cap B would have to be fairly large. This would considerably increase the spectrograph's volume and pump down time. The volume could be decreased by using a single cap and a flat plate to close the ends. However, interchanging the cap and plate would be troublesome and would require removal of either the grazing incidence plate holder and supporting structure or instrumentation likely to be installed for normal incidence work. Furthermore, burying the grazing incidence light source and entrance slit inside the vacuum chamber would be difficult.

4.03.04: Possible Arrangement Number Two

The second possible arrangement for inclusion of both normal and grazing incidence provisions is indicated by figure 4.03.04A.

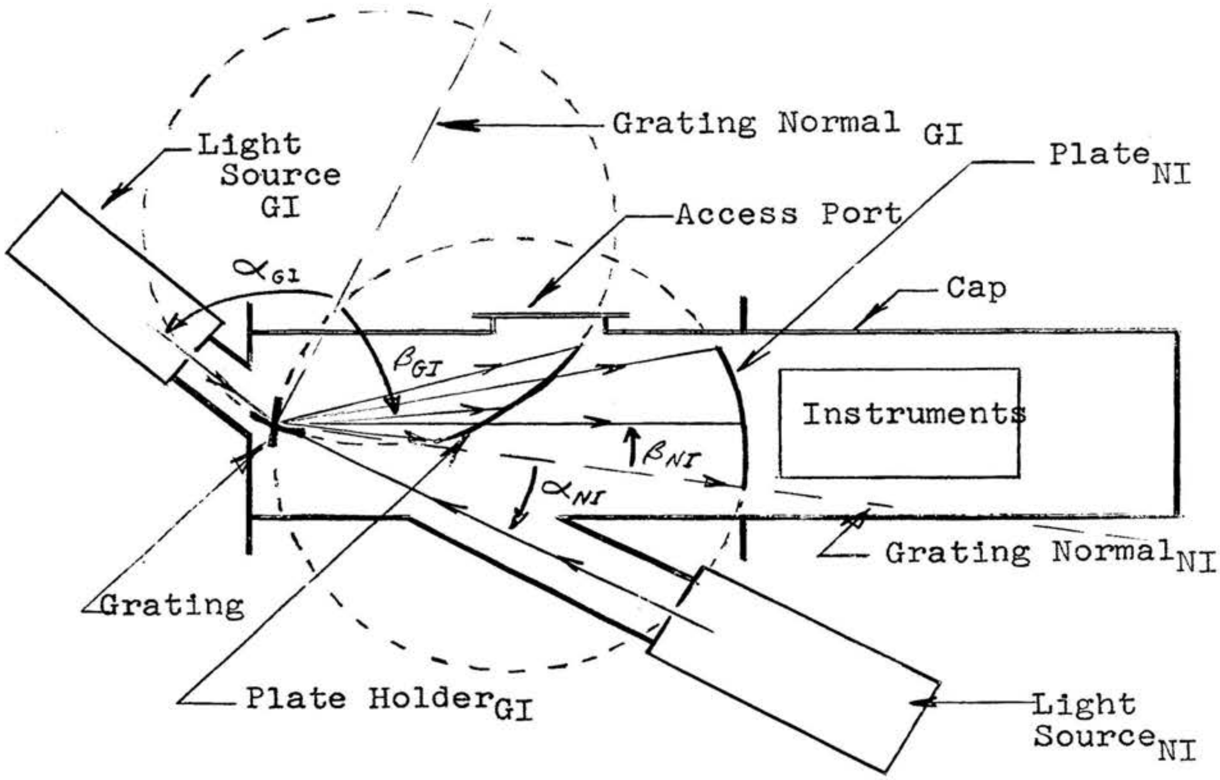

Figure 4.03.04A: Possible Arrangement for Combined Normal and Grazing Incidence

With this arrangement, conversion from normal to grazing incidence requires grating rotation and possible installation of a removable plate holder. Although conversion of this instrument would involve removal or insertion of the grazing incidence plate holder or other detection apparatus, proper design would allow such conversions without need for realignment.

This arrangement does not provide as much accessability to the grazing incidence plate holder as the 4.03.03 arrangement. However, the inclusion of access ports in the vacuum chamber greatly reduces this objection. It is also possible to make the girder supporting the grating and the plate holder removable. In this design, alignment pins maintain its correct position relative to the entrance slit.

The figure 4.03.04 arrangement is more compact than that shown in figure 4.03.03. The vacuum chamber volume is less and the pump down time is shorter. A flat flange is used instead of the large end cap required for the other arrangement. The figure 4.03.04 arrangement also gives good accessibility to the light source and entrance slit. Hence, the problem of providing a light source for grazing incidence is considerably reduced.

4.04.00: Spectrograph Description and Design Philosophy

4.04.01: Spectrograph Type and Arrangement

In order to cover effectively the entire vacuum ultraviolet with the same instrument, a combination grazing-incidence, normal-incidence spectrograph was designed. The basic arrangement of the instrument is along the lines desecribed in section 4.03.04, however the section 4.03.03 arrangement may be used if necessary. A detailed plan of the entire instrument indicating exact locations of the principal elements is shown in figure 4.04.01A. The assembled spectrograph is shown by figure 4.04.01B.

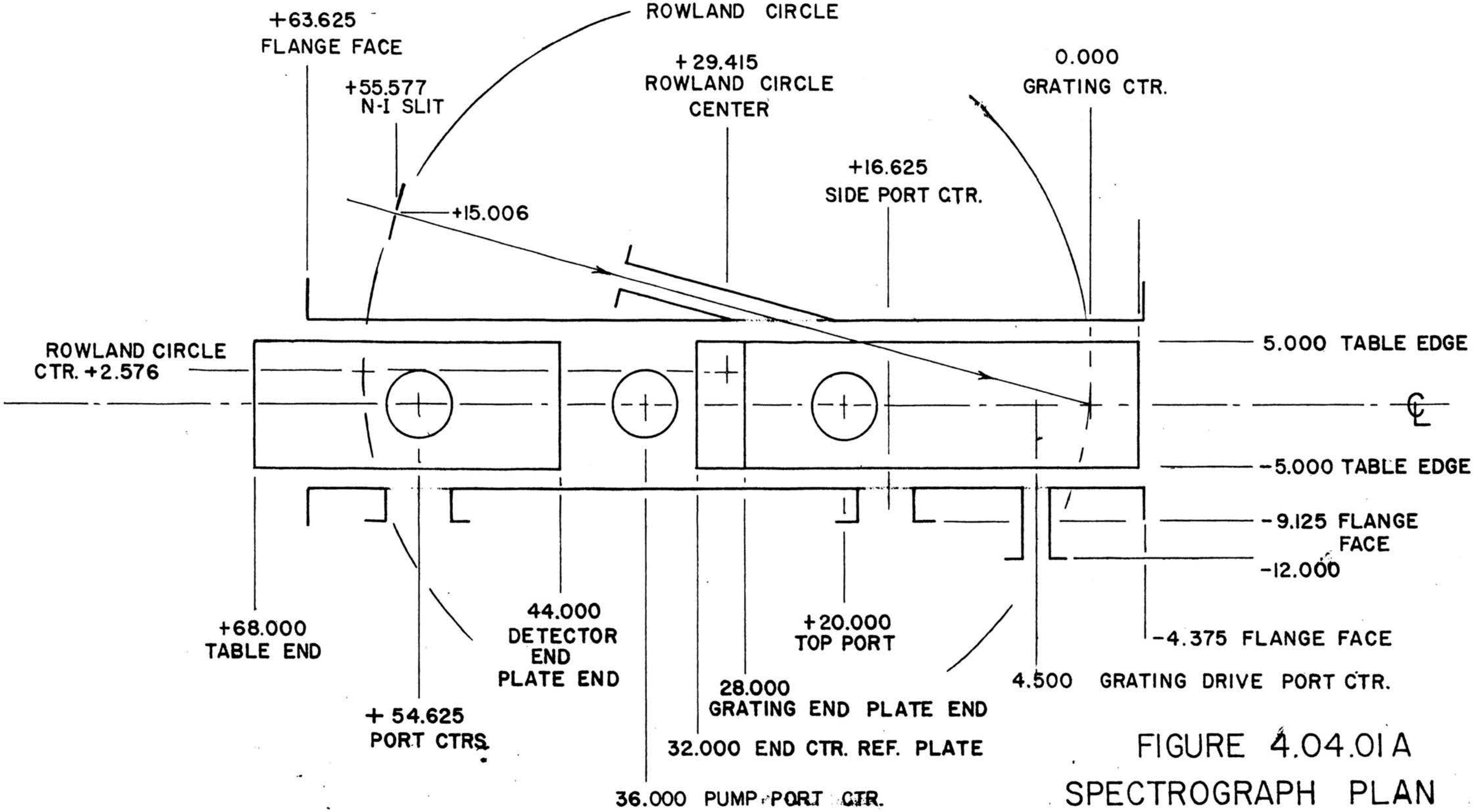

FIGURE 4.04.01A
SPECTROGRAPH PLAN

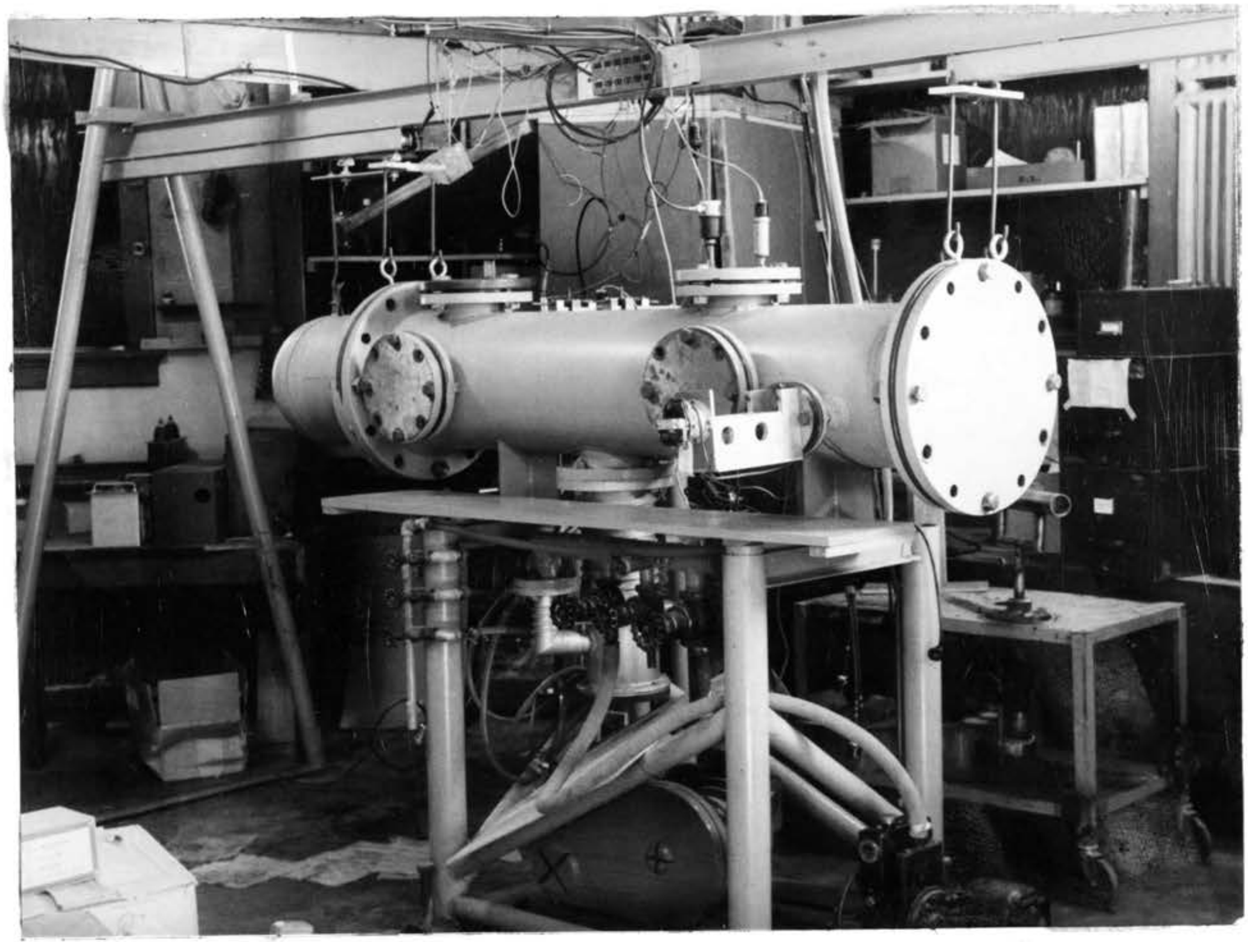

Figure 4.04.01B: Assembled Spectrograph Showing Main Vacuum Chamber Mounted on Supporting Stand with Vacuum Pumps Installed Under the Main Vacuum Chamber.

4.04.02: Girder Mounting of Optical Elements

All of the optical elements of the spectrograph except the entrance slits are mounted to a rigid girder. This girder may be removed easily from the vacuum chamber without disturbing the alignment of the components it supports. This provision makes it possible to perform most equipment installation and alignment operations on the bench outside the limited confines of the vacuum chamber. Return of the girder to precisely the same position relative to the entrance slits each time is assured by the use of steel dowel pins through the girder and its mounting pads inside the vacuum chamber. Hence, alignment and focus for both normal and grazing incidence is always preserved.

A built in focusing tool is included on this girder to permit rapid location of the normal incidence focal circle. By the attachment of a side arm to the girder, this same tool could also be used for rough grazing incidence alignment.

Detailed descriptions of both the girder and the alignment tool are given in section 7.00.00 of this thesis.

4.04.03: Mounting Plate Philosophy

In order to facilitate the installation of equipment, provide flexibility and to make possible the preservation of the basic instrument, a system of mounting and base plates is used in this spectrograph. All internal equipment is mounted on one of two removable mounting plates that are supported by and accurately indexed to the girder. Tapped bolt and alignment pin holes are provided in these plates to accommodate both present and any future equipment without marring the basic plates by drilling additional holes. Locations of these holes are given in section 7.00.00. Use of these holes for equipment mounting instead of indiscriminate drilling of additional holes will mean that the expensive mounting plates will be preserved for indefinite use without decrease in usefulness or loss of accuracy.

All components such as the grating mount and film holders for use inside the vacuum chamber are built upon separate base plates that have mounting and alignment holes to match the mounting plate holes. This system offers two advantages: The base plates provide a convenient means of supporting the various parts when not installed in the spectrograph; and their use allows the equipment to be removed and re-installed without loss of alignment. Because such plates are normally small, they are less expensive than the larger precision drilled mounting plates. Hence, it is far more desirable to mount small parts and subassemblies on such plates than directly to the more expensive mounting plates. This philosophy is covered in more detail in section 7.00.00.

4.04.04: The Grating Mount

The grating mount provides for rotation of the grating about all three axes and translation of the Y and Z axes along the X axis as indicated figure 4.04.04A

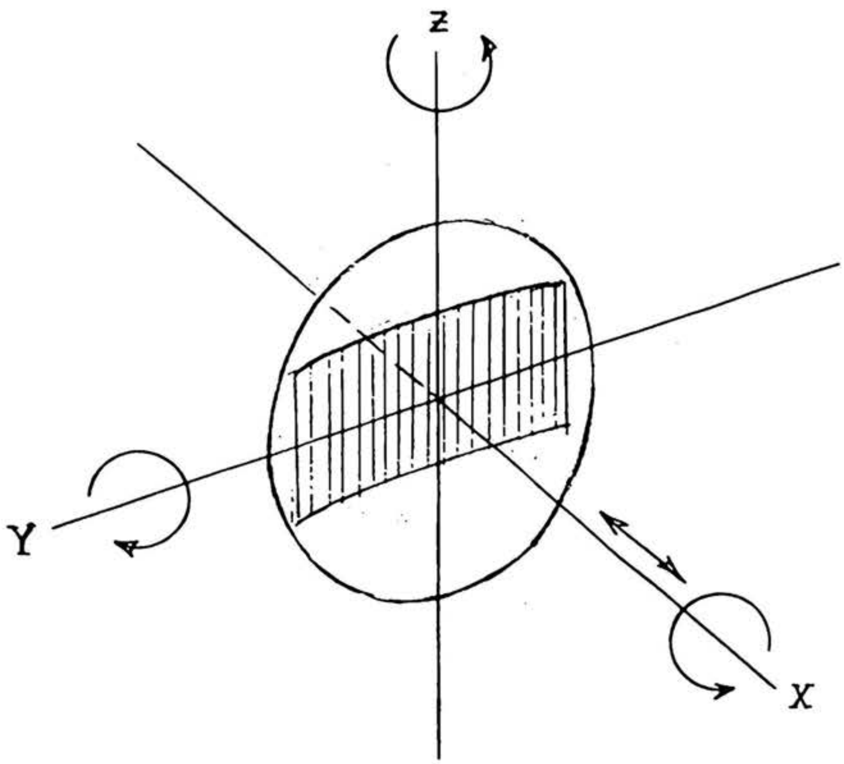

Figure 4.04.04A: Possible Motions Provided by Grating Mount

Approximately ten degrees of rotational freedom are provided about the Y axis to enable precise alignment of the X axis in a horizontal plane. Approximately seven and one-half degrees of rotational freedom are provided about the Z axis. The grating may be rotated in azimuth either manually or by a synchronous motor outside of the vacuum chamber. The motor allows rocking of the grating for scanning purposes at normal incidence. Shifting of the grating in azimuth for conversions between normal and grazing incidence operation is accomplished by lifting a link between the drive mechanism and the grating drive arm and rotating the grating mount to the alternate position. A vernier scale on the drive box outside the vacuum chamber allows the grating to be returned manually to any desired azimuth setting with sufficient precision to secure correct alignment for both grazing and normal incidence. The grating holder may be rotated 180 degrees about the X axis. A fine X rotation of a few degrees may be made to allow alignment of the rulings precisely in a vertical plane. (As the same grating must be used alternately with both the grazing and normal incidence slits, the rulings must be aligned to a vertical and the two slits made parallel to the grating rulings.) Translation of the grating along the X axis is provided by a thumbscrew adjustment so that the center of the grating may be fixed so that azimuth rotation is about the Z axis of the grating. This is not a focusing adjustment. (Because the grating must be used for both normal and grazing incidence, focusing must be accomplished by adjusting the slits and plate holders to the grating.) Index marks, keying pins and the vernier scale on the drive box allow the grating mount to be removed and re-installed without loss of adjustment. A more detailed description is given in section 5.00.00.

4.04.05: Normal Incidence Plate Holder

The normal incidence plate holder is made from two cast aluminum plates having 75 cm radius Rowland Circle segments milled in them. It will accept either 35 mm strip film or 1.25 inch glass spectrograph plates. The holder is attached to its support by four 0.25 inch pins and may be removed from the spectrograph through a side access port after lifting it from these pins. This makes it possible to load film into the holder with it outside of the spectrograph. Alignment is not disturbed by such operations.

The film holder is supported by a positioning mechanism that provides both focusing adjustments and a means for remotely raising or lowering the plate relative to a mask. The latter provision permits multiple exposures on the same plate. After focusing is completed, all adjustments may be locked. The entire positioning assembly may then be removed and replaced without loss of adjustment. Correct position on the mounting plate is maintained by two 0.25 inch alignment pins. The positioning assembly is shown in figure 4.04.05A.

A mask with a narrow horizontal slit is located just in front of the plate holder to allow multiple exposures. When aligned with the focused plate holder, this mask serves as a Rowland Circle reference in the absence of the plate holder and support. Other apparatus may be located easily in relation to the focal circle by using the mask as a reference.

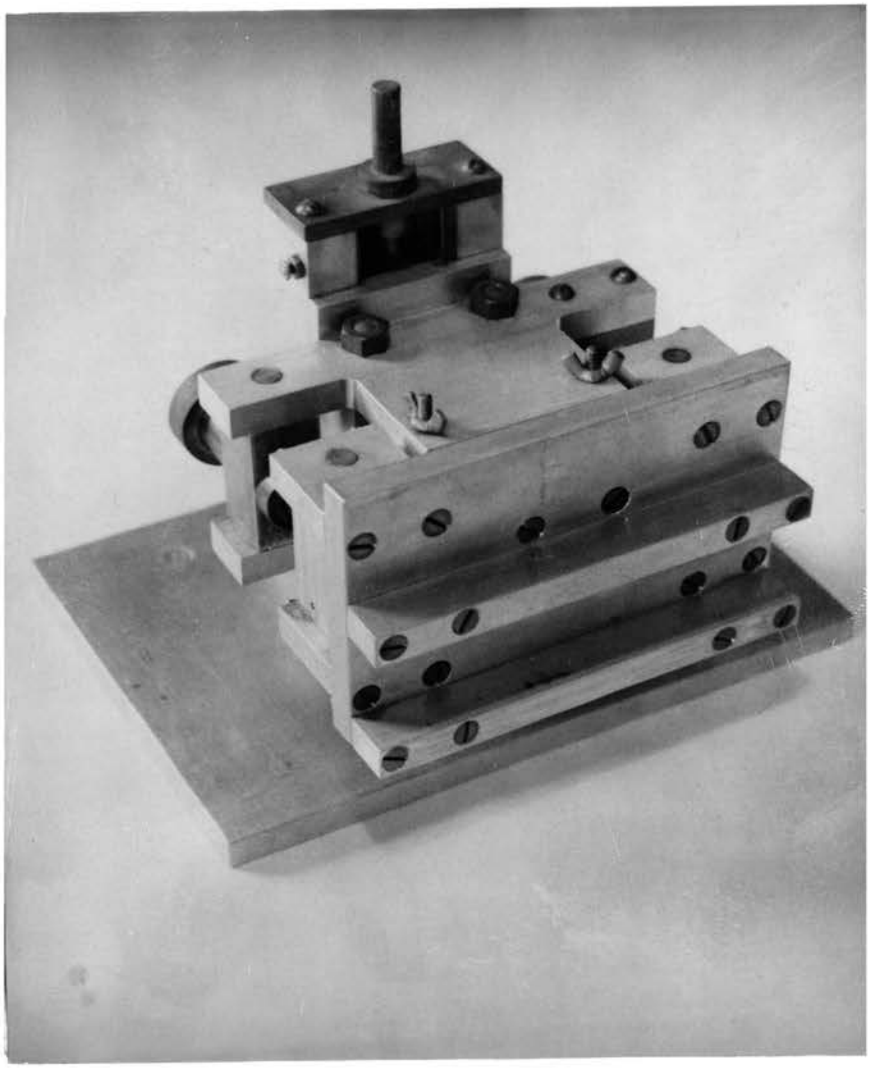

Figure 4.04.05A: Positioning Assembly

The mask is held in place on its support by two pins. Removal of one pin allows it to swing away for removal of the plate holder. Two alignment pins preserve alignment if the mask assembly is removed. The mask assembly is shown in figures 6.00.00-B and 6.02.00-B & E.

Complete descriptions of the plate holder, positioning mechanism and mask assembly are given in section 6.00.00.

4.04.06: Grazing Incidence Plate Holder

Shortage of time prevented completion of the design and construction of a separate plate holder for grazing incidence. Such a plate holder should be constructed and located in accordance with the computations in section 4.06.00. It should be constructed on a removable base plate and mounted on the grating end mounting plate in the position indicated in figure 4.04.01A. The base plate should be pinned to the mounting plate to preserve alignment during removal and reinstallation.

The original intent was to use the plate holder from the Chaplin(1) spectrograph. A study of this plate holder indicated that it could be easily adapted for use in this instrument. The plate holder could be removed from its present base and mounted on a base plate suitable for installation in this instrument.

(1) Chaplin, Op. cit.

The normal incidence plate holder is probably suitable for grazing incidence use. Study of this possibility indicated that a relatively simple support could be constructed to allow its use.

More detailed suggestions for a grazing incidence plate holder are given in section 10.00.00.

4.04.07: The Vacuum Chamber

All normal and grazing incidence optical components except the entrance slits are mounted inside a fourteen inch diameter steel vacuum chamber. The girder mentioned in section 4.04.02 is supported by and pinned to carefully aligned steel mounting pads welded into the ends of the main chamber.

The main chamber is a 14 inch O.D., 3/8 inch wall mild steel pipe with suitable flanges electrically welded to it at the ends and other necessary points. The grating end is closed by a 21 inch steel flange. The opposite end is closed by an 18 inch long steel cap.

The vacuum chamber, mounted on its supporting stand, is shown in figure 4.04.01B. A complete description is given in section 8.00.00.

4.04.08: Component Accessibility

Considerable effort was expended toward insuring accessibility of components mounted inside the vacuum chamber. In addition to mounting all components on a removable girder, access ports have been placed at strategic points in the vacuum chamber wall. The two six inch ports on the top of the chamber were located so as to be directly above the normal and grazing incidence plate holders. The two side access ports were located to give proper access to the plate holders to facilitate film loading and other operations. The joint between the main chamber was located at a point that would give good access to the normal incidence focal circle and the space directly behind it. The vacuum chamber center line was located at the optimum height for inside accessibility.

4.04.09: Support

The vacuum chamber is supported by a rigid, welded tubular steel stand. This stand supports the main chamber at two points. Bolt on points have been provided for independent support of the normal incidence light source and its pumping system rigidly in position relative to the main chamber. This provision facilitates mounting of the light source and eliminates the need for supporting it from the main chamber. Cap screws in the legs of the stand provide for leveling of the spectrograph.

The support stand is described in section 9.00.00.

4.04.10: End Cap Handling

The 21 inch steel plate at the grating end of the spectrograph and the end cap at the opposite end are quite heavy and would be difficult and even dangerous to handle without support. Consequently, an overhead trolley is used to provide the support. A fourteen foot "I" beam supported by welded tubular steel legs runs overhead. Ordinary barn door track is welded to the "I" beam. Barn door trolleys support the loads and allow them to be rolled back from the vacuum chamber.

This overhead trolley is described in detail by section 9.00.00.

4.04.11: Light Source Mounting

Although neither of the light sources were constructed as a part of this thesis problem, provision for light source mounting was a necessary part of the spectrograph design. Hence a description of the available mounting methods is in order.

A two inch side arm running from the main vacuum chamber toward the required normal incidence light source position was provided. This line was terminated at a two inch Vacuum Research[1] type VG-102 gate valve to isolate the light source from the main vacuum system. The flange face of this valve on the light source side is 44.70 $\pm$0.10 inches from

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(1) Vacuum Research Co., Op. cit.

the center of the grating. The remaining distance between the flange face and the required slit position was left for the light source line and focusing bellows.

Provisions for supporting the light source and slit assembly on the mounting stand are described in sections 4.04.09 and 9.00.00.

Because the grating and a common adjustment is shared between normal and grazing incidence, provision must be made in both light source lines for accurately positioning the slits relative to the grating.

The grazing incidence light source line would be very short. (The required slit location is given in section 4.06.00.) Consequently, the most practical means of mounting is probably to mount it on and support it by the 21 inch end plate of the vacuum chamber. The method used by Chaplin[1] appears to be satisfactory for this application. In order to minimize gas leaks into the system from the light source, it would probably be desirable to run a suitably baffled tube with separate pumping through the end plate to a point near the grating. Such a tube could also contain ion traps to protect the grating from ion bombardment from the nearby light source.

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(1) Chaplin, Op, cit.

4.04.12: Pumping System

The main vacuum chamber is evacuated by a High Vacuum Corporation type HV-6F, six inch oil diffusion pump backed by a Welch type 1397B forepump. With this system, the diffusion pump turn on pressure of 200 microns can be reached within about ten minutes. Warm-up and outgassing of the diffusion requires approximately one-half hour. Pressures of less than 0.1 micron can be reached within one hour. Bankoff pressure with HV-40 oil is given by the diffusion pump manufacturer as 1.5×10^{-6} mm Hg.

In addition to the main pumping system, a smaller forepump is used to keep the system pumped down when not in use to discourage gas adsorption and oxidation of the inside of the steel vacuum chamber.

A detailed description of the pumping system and its capacity is given in section 11.00.00.

4.04.13: Vacuum Gauging

Two types of vacuum gauges are installed in the vacuum system and a third is available. Thermocouple gauges are used at various points to cover the range between 1 and 1000 microns. Phillips cold cathode ionization gauges are used for lower pressures. The power supply and control unit for hot cathode ionization gauges is available on the control panel.

4.04.14: Control Panel

As far as possible, all operating controls, vacuum gauges and power fuses are consolidated on two 19 inch relay racks. Only vacuum valves and cooling water controls are located elsewhere. This arrangement simplifies operation, leads to a more orderly laboratory and provides a means of keeping the operator away from high voltage light source power supplies.

The control panel is shown in figure 4.04.14A.

4.05.00: Normal Incidence Provision

4.05.01: Design Goals and Range

The normal incidence portion of this instrument was designed to cover the range, in first order between the central image and 2000 Angstroms. Both the direct image and grating normal were required to fall on the same spectrograph plate. Provision for multiple exposures on a single plate was also required.

In order to permit effective use as a monochromator, provision for scanning the lines of the spectrum past a fixed point at the detection end was required.

4.05.02: Angle of Incidence

In order to cover the zero to 2000 Å range with the minimum length film plate and have the grating normal usable on this plate, the angle of incidence (α) must be that required to cause the first order 2000 Å line to fall along the grating normal. Setting β = zero, λ = 2000 Å, n = 1 and $d = 1.141 \times 10^4$ Å in the grating equation,

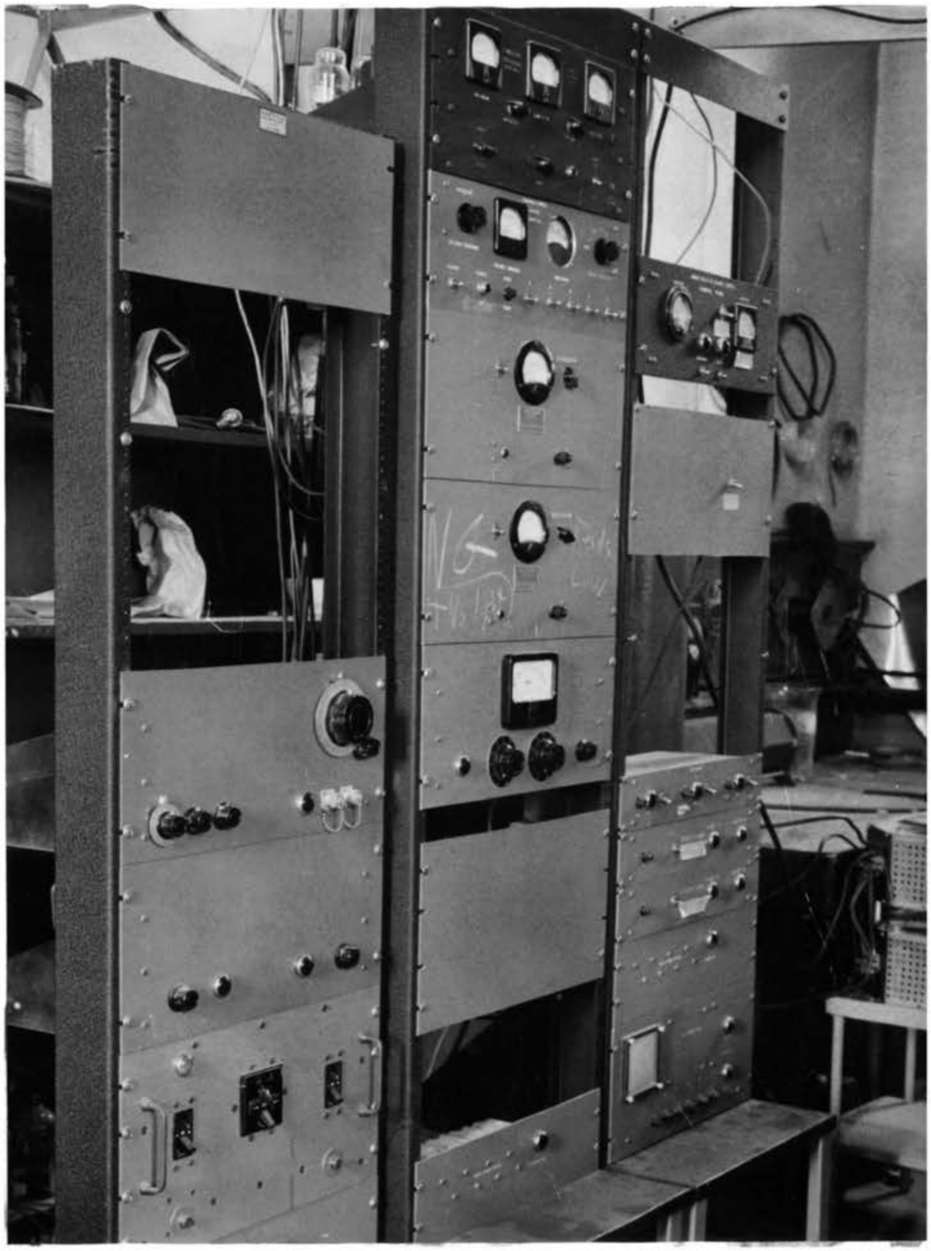

Figure 4.04.14A: Control Panel Showing Rack Mounted Spectrograph Controls and Vacuum Gauge Panels

$$\not\angle\, n\lambda = d\ (\sin\alpha - \sin\beta) \qquad (3.06.02A)$$

gives $\sin\alpha = \dfrac{2000}{1.141 \times 10^4}$

There, the desired angle of incidence is

$$\alpha = \text{Arcsin } 0.1753$$

or $\alpha = 10^\circ\ 5'$. (4.05.02A)

4.05.03: Diffraction angle for Zero Wavelength

From the grating equation, α equals β for λ equal to zero. Therefore, the zero wavelength images are formed at the position of the direct image on the film plate. As α equals $10^\circ\ 5'$, the zero wavelength images are formed at a point on the Rowland Circle $10^\circ\ 5'$ from the grating normal.

4.05.04: Optical Orientation in the Vacuum Chamber

The orientation of the normal incidence spectrograph components in the vacuum chamber is governed by the need to use the smallest possible volume and the intended uses of the instrument. In the arrangement selected, (see fig. 4.01.01A) the width of the vacuum chamber is dictated by the normal incidence plate holder length. In order to minimize the chamber width, the optics are arranged so that the grating normal (2000 Å line) falls near one side and the direct image falls at the opposite side of the chamber. In order to allow the maximum space for the grating mount, it is centered on the vacuum chamber centerline. The grating normal for normal incidence operation is at an angle of five degrees with the chamber centerline. The entrance slit is located at the end of a side tube set to an angle of 15 degrees with the main chamber centerline.

The break point between the end cap and the main chamber is so located as to allow direct observation of both the direct image and the grating normal when the cap is removed. This capability is helpful in aligning the instrument. The deep end cap permits mounting of experimental apparatus behind the focal circle.

4.05.05: Grating Location

The center of the grating is located at the vacuum chamber centerline near one end of the chamber. This point is designated by the coordinates (0;0;0). (See section 1.05.00 for coordinate system description.) The grating center is indicated by point A in figure 4.05.05A.

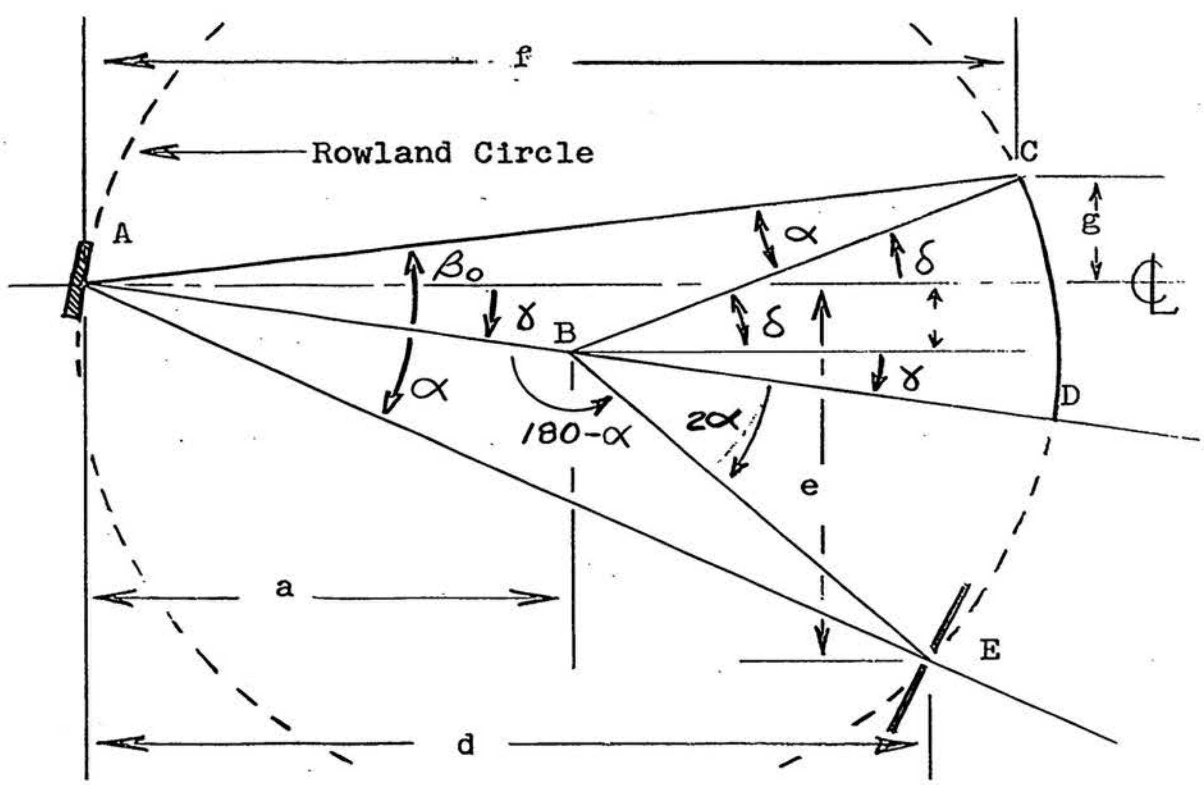

Figure 4.05.05A: Normal Incidence Geometry

4.05.06: Coordinates of Rowland Circle Center

The center of the Rowland Circle is at a point on the grating normal 75 cm (29.5275 inches) from the grating. (Point B in figure 4.05.05A.) The distance (a) along the spectrograph centerline is

$a = (AB) \cos \gamma$, where $\gamma = 5^{\circ}$ and $(AB) = 29.5275$ inches.

Therefore, $a = 29.415$ inches. (4.05.06A)

The distance (b) from the centerline is $(AB) \sin \gamma$

or $b = 2.576$ inches. (4.05.06B)

Therefore, the coordinates of the focal circle center are (29.415; 2.576; 0).

4.05.07: Entrance Slit Location

From the law of sines, the distance from the grating center to the entrance slit (AE in figure 4.05.05A) is

$$(AE) = \frac{(BE) \sin (180 - 2\alpha)}{\sin \alpha} .$$

α equals $10^{\circ}\ 5'$ and (BE) equals 29.5275 inches.

Therefore, $(AE) = 57.666$ inches. (4.05.07A)

The distance along the centerline (d) is $57.666 \cos(\alpha + \gamma)$.

The angle $\alpha + \gamma$ is $15^{\circ}\ 5'$, therefore

$d = 55.677$ inches. (4.05.07B)

The distance from the centerline (e) is $57.666 \sin(\alpha + \gamma)$ or

$e = 15.006$ inches. (4.05.07C)

Therefore the coordinates of the entrance slit are (55.677;15.006;0).

4.05.08: Normal Incidence Film Plate Position

The distance of the point D in figure 4.05.05A from the grating along the centerline is $\left[(AB) + (BD)\right] \cos \gamma$. Since AB equals BD, this distance is equal to 2a or 58.830 inches. The distance of the point D from the centerline is equal to 2b or 5.152 inches. Therefore the coordinates of the intersection of the focal circle and the grating normal are

$$(58.830;\ 5.152;\ 0). \qquad (4.05.08A)$$

The distance (f) of the point C from the grating along the centerline is $(AC)\cos(\beta_0 - \gamma)$. (AC) equals (AE) which from equation 4.05.07A is 57.666 inches. For the zero wavelength line, β equals α. Therefore, $(\beta_0 - \gamma)$ is $10^\circ\ 5'$ minus 5° or $5^\circ\ 5'$. Therefore (f) equals 57.439 inches. Likewise, the distance (g) from the centerline is $(AC)\sin(\beta_0 - \gamma)$ which equals 5.419 inches. Therefore, the coordinates of the zero wavelength image are

$$(57.439;\ -5.419;\ 0) \qquad (4.05.08B)$$

4.05.09: Dispersion at Normal Incidence

Setting $R = 1500$ mm, $d = 11{,}410$ Å, $n = 1$ and β = zero in equation 3.06.02B gives the linear dispersion, $ds/d\lambda$, of the spectrograph for first order lines at the normal (2000 Å line) to be 0.1314 mm/Å.

At the other end of the plate holder (zero Å line) $\beta = 10^\circ\ 5'$ resulting in a linear dispersion of 0.1324 mm/Å.

4.05.10: Astigmatism at Normal Incidence

Substituting β and α for the 2000 Å line image into equation 3.06.02C gives the astigmatism as 0.031 inches for use of the full one inch length of the rulings. For the maximum β of 10° 5', the astigmatism increases to only 0.061 inches.

4.05.11: Wavelength Range as Monochromater

When used as a monochromater, the detection apparatus or sample of material to be irradiated is placed behind a second slit located on the focal circle and the spectrograph centerline. In this application, the wavelength desired at the second slit is selected by adjusting the angles of incidence and diffraction by rotating the grating about its Z axis.

Assuming that the second slit is placed on the centerline, the maximum angle of incidence is 15° 5'. Using $\alpha = 15^\circ$ 5' and setting β equal to zero in the grating equation gives the maximum obtainable wavelength (λ_m) as

$$\lambda_m = 1.141 \times 10^4 \ (\mathrm{SIN}\ 15^\circ\ 5')\ \text{Å}$$

or $$\lambda_m = 2{,}969\ \text{Å} \qquad (4.05.11A)$$

Therefore, the theoretical range of the instrument when used as a monochromater is zero to 2,969 Angstroms.

4.05.12: Defocusing of 2969 Angstrom Line

Defocusing caused by rotation of the grating will be greatest for the line for which β departs most from the best focus β. This is the 2969 Angstrom line. Substituting $\beta = 5^\circ$, $\theta = 15^\circ$ and $d\beta = 5^\circ$ into equation 3.04.04E in terms of radians gives:

$$dr' \approx 0.012\ R$$

The width of the grating used is approximately fifty millimeters and R = 1500 mm. Therefore the image width resulting from defocusing will be approximately 0.6 mm for the 2969 Angstrom line.

4.06.00: Grazing Incidence Provision

4.06.01: Design Goals and Range

The range and angle of incidence for the grazing incidence portion of this instrument were dictated to some extent by the desire to allow use of Chaplin's[1] film holder. The range was further limited by the desire to accommodate the grazing incidence elements in the minimum size vacuum chamber required for the normal incidence provision. The desired range was 100 to 1000 Angstroms with first order lines.

4.06.02: Angle of Incidence

Although a larger angle of incidence would have been desirable in order to give coverage below 100 Angstroms, an incidence angle of 80 degrees was selected. According to Sawyer[2], this angle will permit observations down to approximately 75 Angstroms. Therefore, this angle should give adequate coverage down to the required 100 Angstrom point. The reasons for selection of the 80 degree incidence angle were: (1) The Chaplin[3] film holder had been constructed for this angle and (2) Mounting a light source in closer proximity to the grating as would be necessary for a larger angle would have been difficult for a grating of this size, especially when provision for "rocking" the grating was required.

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(1) Chaplin, Op. cit., pp. 28 & 29.

(2) Sawyer, Op. cit., p. 293.

(3) Chaplin, Op. cit.

4.06.03: Angles of Diffraction

As in the case of normal incidence, the zero wavelength image is formed at the diffraction angle equal to the angle of incidence. Hence the grazing incidence direct image will be formed at $\beta = 80^\circ$.

Setting $\lambda = 100$ Å, d = 11,410 Å and $\alpha = 80^\circ$ in the grating equation (3.06.02A) gives diffraction angle (β_{100}) for the first order 100 Å line as 77° 26'. Likewise, the diffraction angle (β_{1000}) for the 1000 Å line is 63° 47.3'.

4.06.04: Optical Orientation in the Vacuum Chamber

The optical orientation of the grazing incidence spectrograph components is shown by figure 4.01.01A. For grazing incidence operation, the grating is oriented in azimuth so that its normal is at an angle of 77 degrees with the instrument centerline. This orientation represents a compromise between light source mounting convenience and placing a 100 to 1000 Angstrom film holder in the minimum size vacuum chamber required for the normal incidence provision.

Access to the grazing incidence plate holder without removing the mounting plate from the instrument is provided by six inch ports in the side of the vacuum chamber at S.L. 16.625 and on the top at S.L. 20.000.

4.06.05: Rowland Circle Location

The center of the Rowland circle is located at point (A) in figure 4.06.05A.

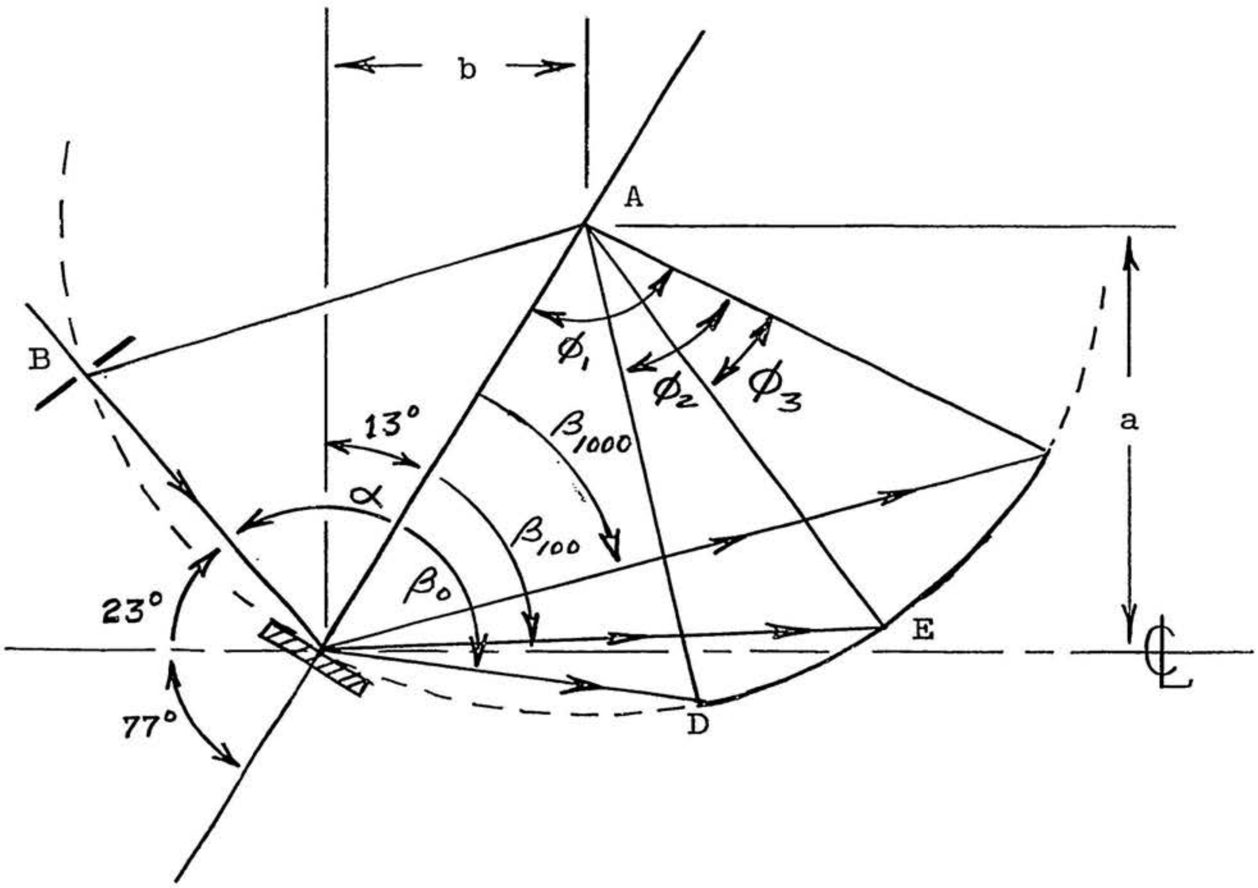


Figure 4.06.05: Grazing Incidence Geometry

The distance (a) of the Rowland Circle center from the centerline is (CA) SIN 77°. (CA) equals the Rowland Circle radius (29.5275 inches).

Hence $\quad a = 28.771$ inches. $\qquad$ (4.06.05A)

The distance (b) from the grating center along the centerline is $\quad$ (CA) COS 77° or

$b = 6.642$ inches. $\qquad$ (4.06.05B)

4.06.06: Entrance Slit Location

The grazing incidence entrance slit location is denoted by (B) in figure 4.06.05A. From the law of sines, the distance (CB) from the grating center to the slit is

$$(CB) = \frac{(CA)\ \mathrm{SIN}\ (\pi - 2\alpha)}{\mathrm{SIN}\ \alpha} .$$

The angle α equals 80° and (CA) equals 29.5275 inches.
Therefore (CB) = 10.255 inches (4.06.06A)

As the angle between (CB) and the centerline is 23 degrees, the coordinates of the entrance slit are (-9.440; -3.997; 0).

4.06.07: Grazing Incidence Film Plate Length

The length of the film plate required to cover the range between the 100 Å line and the 1000 Å line is given by (AD) ϕ_3, where ϕ_3 as defined by figure 4.06.05A is in radians. Examination of figure 4.06.06A reveals that ϕ_3 is equal to $2(\beta_{1000} - \beta_{100})$. From 4.06.03, $\beta_{1000} = 63^\circ\ 47.3'$ and $\beta_{100} = 77^\circ\ 26'$. Therefore $\phi_3 = 27^\circ\ 17.4'$. Hence the plate length (DF) is 12.029 inches.

4.06.08: Grazing Incidence Film Plate Location

From the law of sines, the distance (CF) in figure 4.06.05A is given by

$$(CF) = \frac{(AF)\ \mathrm{SIN}\ \phi_1}{\mathrm{SIN}\ \beta_{1000}}$$

The angle ϕ_1 is equal to $(\pi - 2\beta_{1000})$. β_{1000} is equal to $63^\circ\ 47.3'$. Hence ϕ_1 equals $52^\circ\ 25.4'$ and

(CF) = 26.083 inches. (4.06.08A)

The line (CF) makes an angle of $(90 - 13 - \beta_{1000})$ degrees with the centerline. Hence, the coordinates of the 1000 Å line point are (25.312, -5.947, 0).

In like manner, the distance (CE) is found to be

$$(CE) = 14.002 \text{ inches.} \qquad (4.06.08B)$$

The line (CE) makes an angle of $(90 - 13 - \beta_{100})$ degrees with the centerline. Hence, the coordinates of the 100 Å line point are (14.001, 0.105, 0).

The distance (CD) is equal to (BC) or 10.255 inches. The line (CD) is at an angle of $(90 - 13 - \beta_0)$ or 3 degrees with the centerline. Hence, the coordinates of the direct image are (10.241, 0.537, 0).

4.06.09: Dispersion at Grazing Incidence

Setting R = 1500 mm, d = 11,410 Å, n = 1 and $\beta = 77^\circ\ 26'$ in equation 3.06.02B gives the linear dispersion, $ds/d\lambda$, at the 100 Angstrom line as 0.6042 mm/Angstrom.

Likewise, the linear dispersion at the 1000 Angstrom line where $\beta = 63^\circ\ 47.3'$ is 0.2977 mm/Angstrom.

4.06.10: Astigmatism at Grazing Incidence

Substituting $\beta = 77^\circ\ 26'$ and $\alpha = 80^\circ$ into equation 3.06.02C gives the astigmatism as 2.168 inches for use of the full one inch length of the grating rulings. For the 1000 Å line ($\beta = 63^\circ\ 47.3'$) the astigmatism is 3.271 inches.

This large astigmatism indicates that for multiple exposure provisions, a mask can be raised and lowered instead of the film plate. This is an easier task and does not jeopardize the film holder alignment. The complex film positioner required for normal incidence is not necessary.

5.00.00: GRATING MOUNT AND DRIVE MECHANISM

5.01.00: Design Requirements

5.01.01: Adjustment

In addition to the usual requirements for rigid support and adjustments about the three major axes, the lateral translation along the X axis indicated by figure 4.04.04A and provision for "rocking" of the grating about its Z axis were required for this grating mount. The X translation was necessary to allow precise adjustment of the grating Z axis to coincidence with the azimuth rotation of the grating mount.

The grating mount was also required to serve both the normal incidence and grazing incidence spectrograph provisions without change of adjustment except for azimuth rotation. A positive means of returning the azimuth angle to the setting required for correct grazing and normal incidence alignment was desired.

Provision for preservation of all adjustments during removal of the mount from the mounting plate was also required.

5.01.02: Azimuth Rotation

For use as a monochromator, provision for scanning the zero to 2000 Å portion of the spectrum past a slit placed at the instrument centerline was required. A scan time of approximately 20 minutes for this range was desired.

The angle at the grating between the entrance slit and the detection slit is 15 degrees. As the zero Angstrom line is formed at a diffraction angle of $\beta = \alpha$, $\beta_0 = 7.5$ degrees. Hence, the grating normal must be positioned to an angle of 7.5 degrees with the centerline to form the zero Angstrom line image at the detection slit.

For the purpose of determining the diffraction angle for any particular wavelength line formed at the detection slit, the grating equation is written in the form

$$\frac{n\lambda}{d} = 2 \cos \tfrac{1}{2} (\alpha + \beta) \ \mathrm{SIN} \ \tfrac{1}{2} (\alpha - \beta) \qquad (5.01.02A)$$

or

$$\alpha - \beta = 2 \ \mathrm{Arcsin} \frac{n\lambda}{2d \cos \frac{1}{2} (\alpha + \beta)} \qquad (5.01.02B)$$

As $\alpha + \beta = 15^\circ$ and $\alpha = 15^\circ - \beta$ for all settings of the grating azimuth, the diffraction angle for any line image of wavelength λ formed at the detector slit is

$$\beta = 7.5^\circ - \mathrm{Arcsin} \frac{n\lambda}{2d \cos 7.5^\circ} . \qquad (5.01.02C)$$

Setting $n = 1$ and $\lambda = 2000$ Å in (5.01.02C) gives $\beta = 2.43^\circ$ for the 2000 Å line.

The total grating rotation required to scan the zero to 2000 Å range is 7.5 - 2.43 or 5.07 degrees. By providing for an additional 2.43 degrees of rotation, it is possible to rotate the grating to $\beta =$ zero and scan the entire zero to 2969 Angstrom range.

5.02.00: Grating Mount Description

5.02.01: The Complete Grating Mount

The complete grating mount is shown in figure 7.02.01A and by assembly drawings 5.00.00-B, C, E and F (figures 5.02.01-A, B, C and D).

5.02.02: Grating Holder

The grating is recessed into the grating holder (part 5.01.01) and is held in place by the retainer (5.01.02). The retainer has a cut-out to expose the ruled portion of the grating. It is held in place by two ½ inch, 6-32 screws. The grating holder has two small blocks attached to its back side that serve as stops for the X axis alignment screws. The grating holder is symetrical about the Y axis to allow turning the grating 180 degrees about the X axis. The holder is held in place by a 3/8 inch nut (5.01.04) which is locked to the shaft by setscrew 5.01.07S1. A 1/16 inch brass washer (5.01.06S2) is used on each side of cross arm (5.02.01).

5.02.03: Grating Holder Bracket Assembly

The grating holder is supported by the bracket assembly (5.02.00). This bracket holds the X axis adjustment screws (5.02.04-2) and is supported on two ¼ inch pins (5.02.09S2) so that it is free to rotate in such a manner as to allow adjustment of the grating about its Y axis. Y axis rotation torque is applied near the end of the arm extended downward from part 5.02.03.

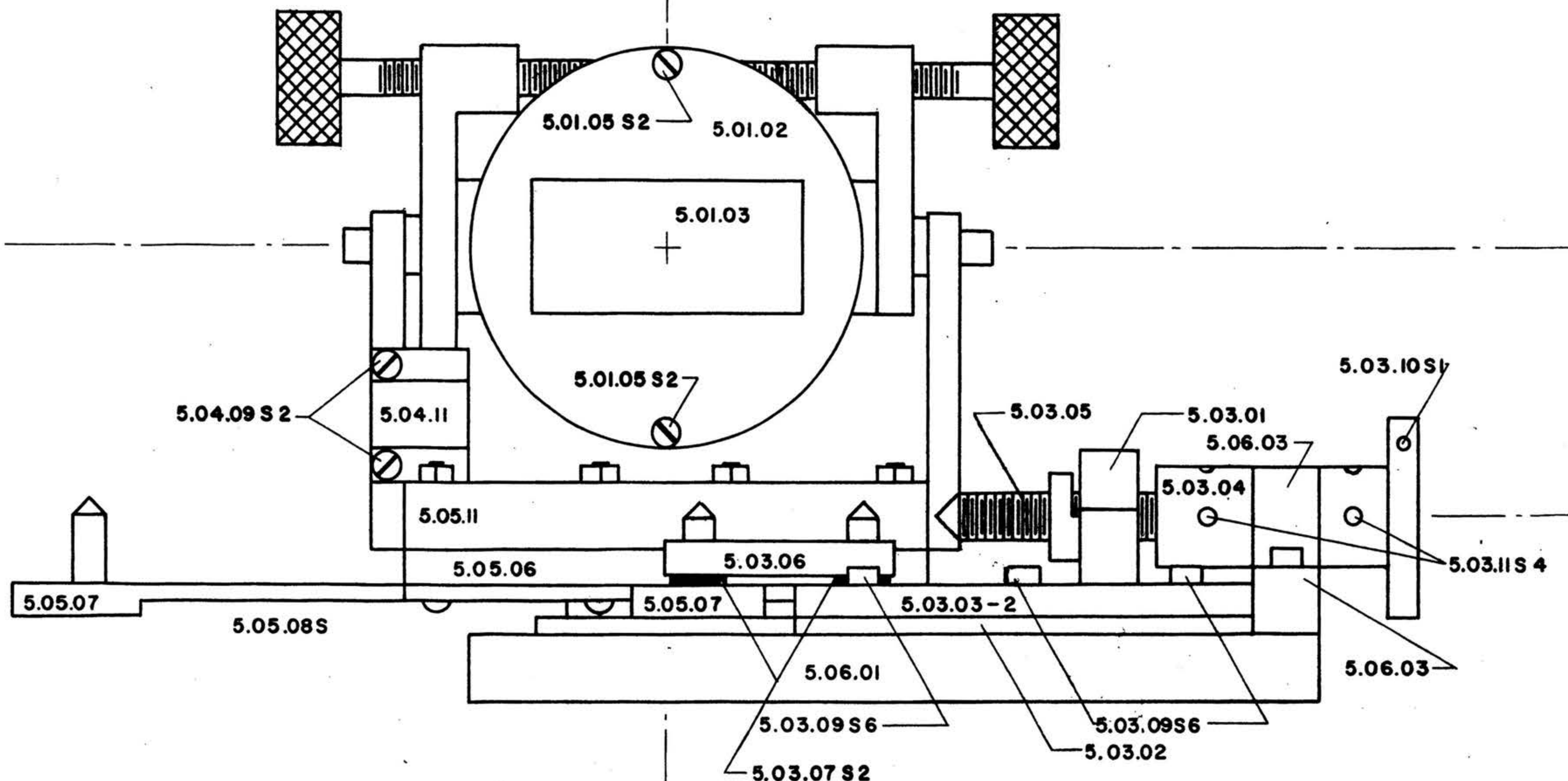


FIGURE 5.02.01A

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH	GRATING MOUNT - FRONT
DRAWING 5.00.00-B	5.00.00

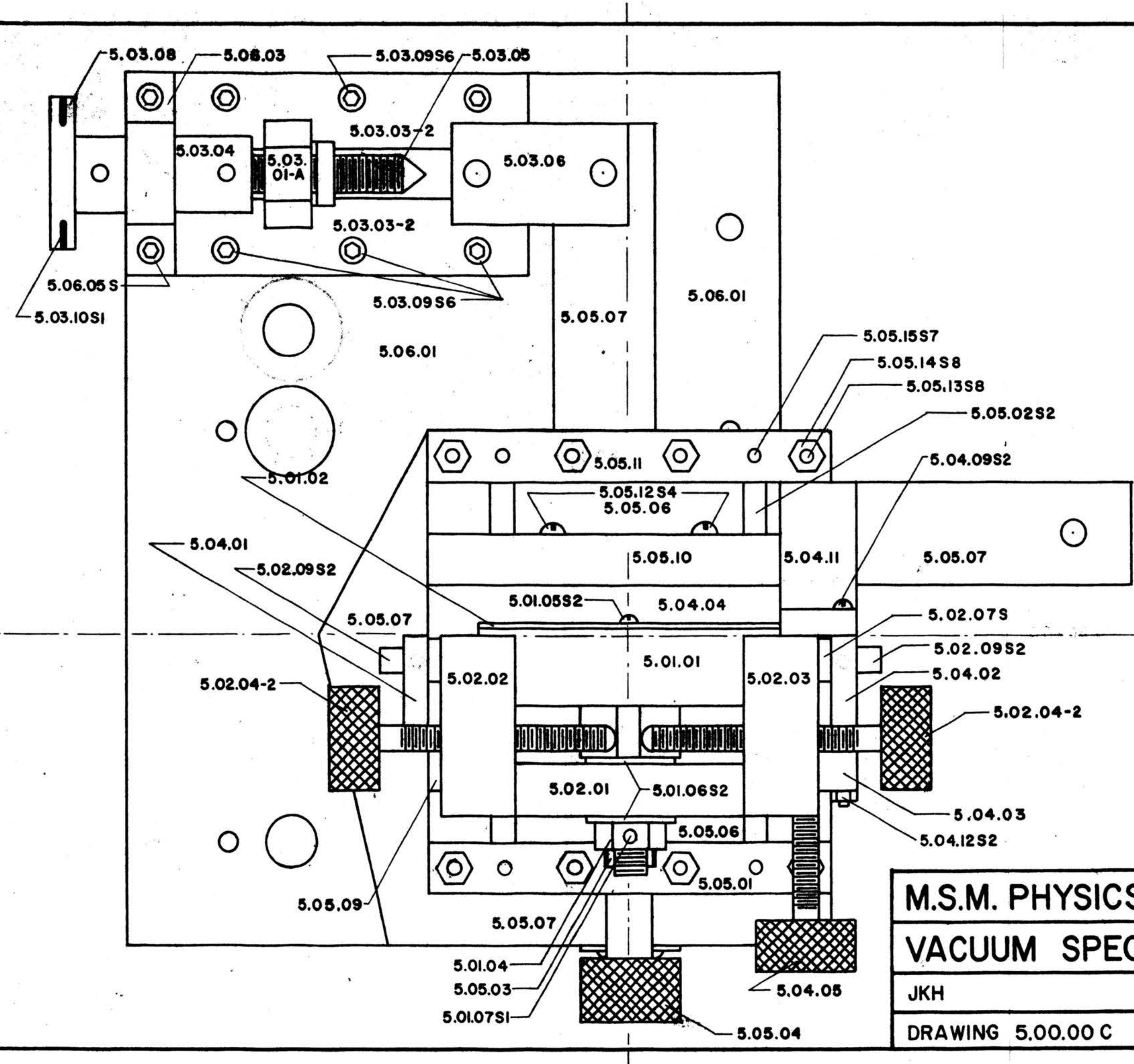


FIGURE 5.02.01B

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH	GRATING MOUNT-TOP VIEW
DRAWING 5.00.00 C	5.00.00

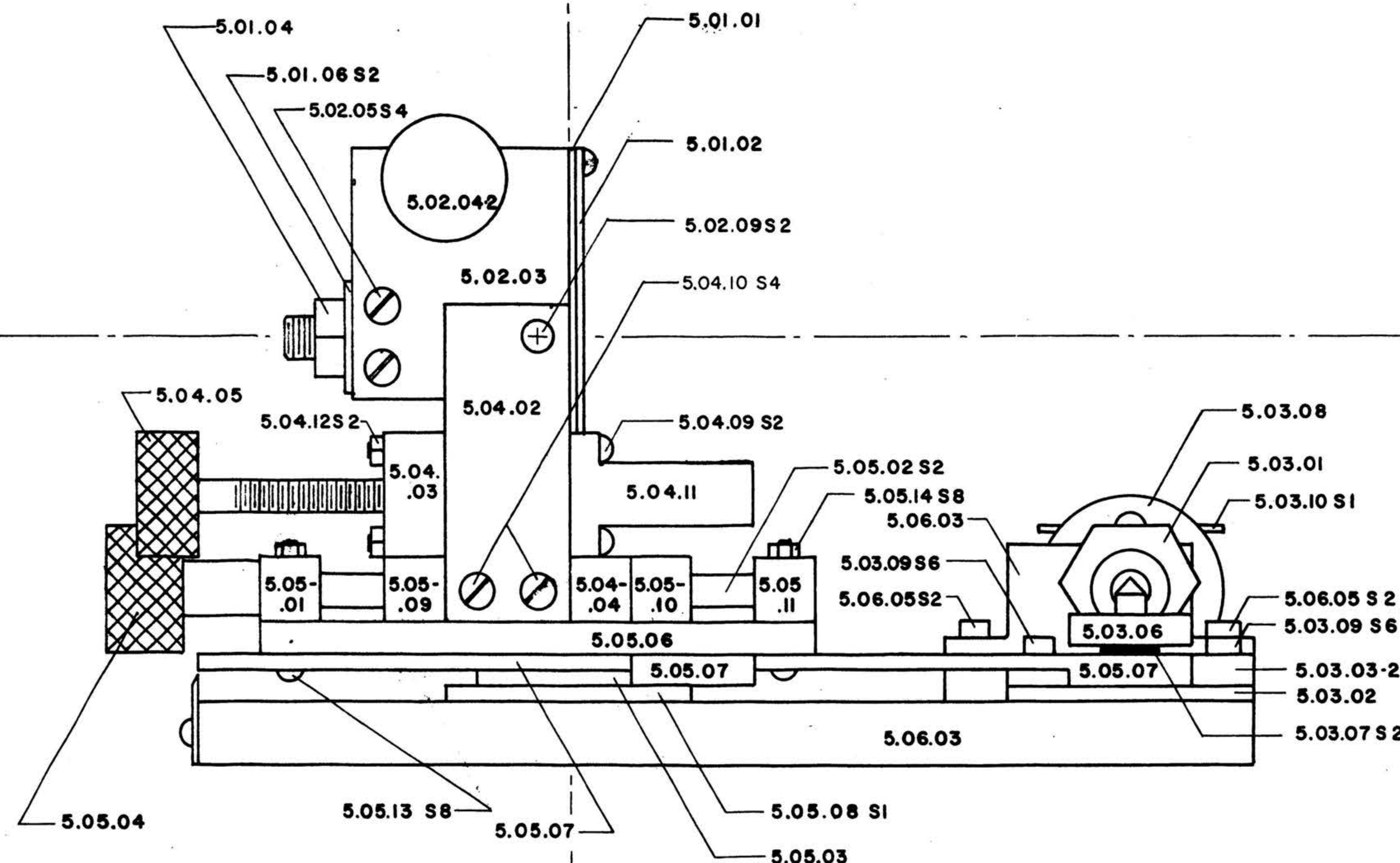


FIGURE 5.02.01 C

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH	GRATING MOUNT-SIDE VIEW
DRAWING 5.00.00-E	5.00.00

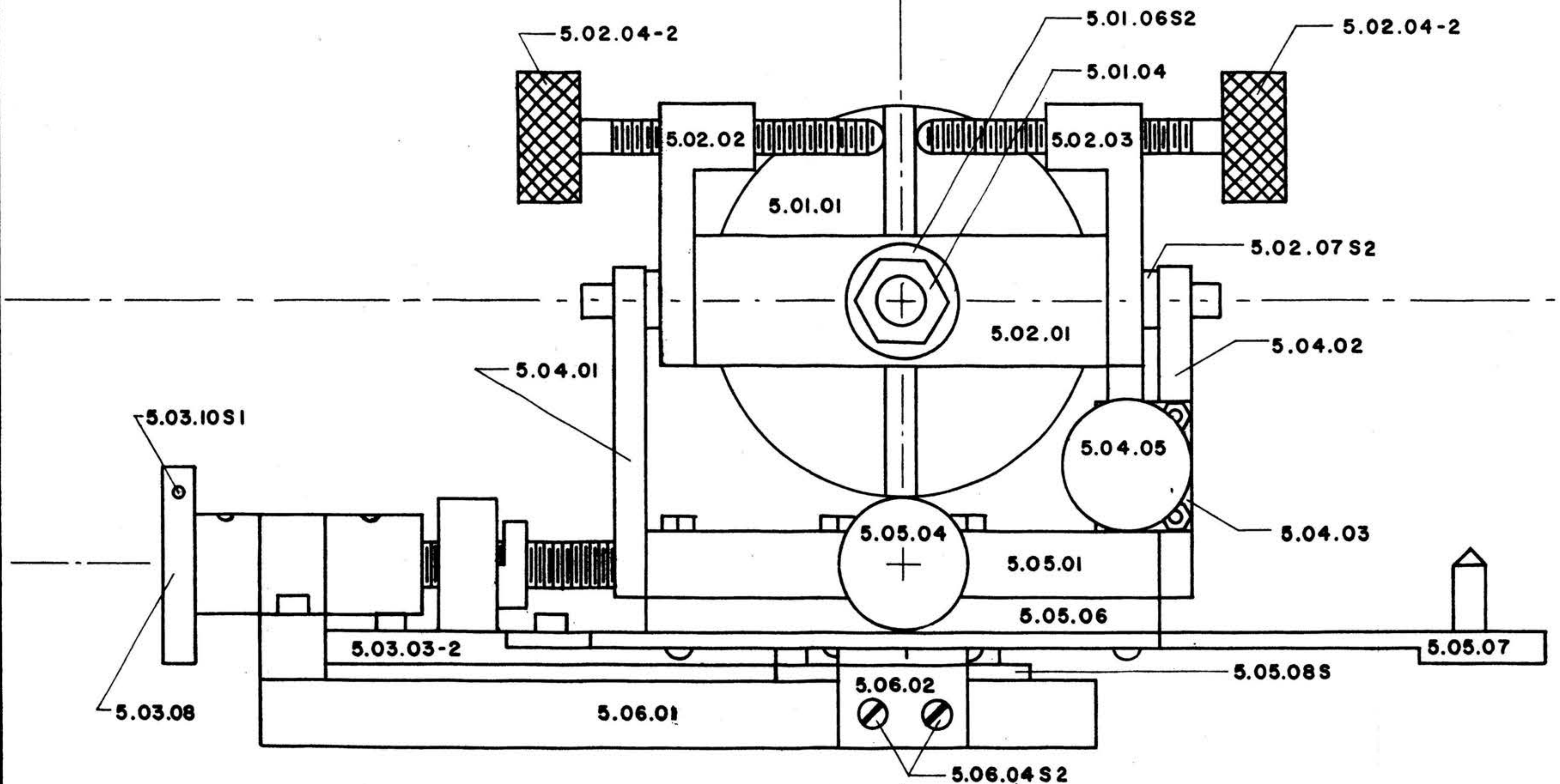


FIGURE 5.02.01D

M.S.M. PHYSICS DEPT	
VACUUM SPECTROGRAPH	
JKH	GRATING MOUNT-REAR VIEW
DRAWING 5.00.00 F	5.00.00

5.02.04: Upper Base Assembly

The bracket assembly (5.02.00) is supported by the upper base assembly (5.04.00) at the points where the two $\frac{1}{4}$ inch pins (5.02.09S2) pass through uprights 5.04.01 and 5.04.02. Adjustment of the grating about its Y axis is governed by thumbscrew 5.04.03 at the rear of the mount. The arm on part 5.02.03 is held firmly against the thumbscrew by a pressure rod (5.04.06) and spring (5.04.07S) inserted into pressure rod holder (5.04.11).

5.02.05: Lower Base Assembly

The upper base assembly is mounted between two guide plates (5.05.09 & 5.05.10) that are free to move along two guide rods (5.05.02S2) mounted regidly to the lower base plate (5.05.06) by rod holders 5.05.01 and 5.05.11. A thumbscrew (5.05.04) restrained by the rear rod holder (5.05.01) turns in threads cut in the rear guide plate (5.05.09) to permit the upper base assembly to be moved along the grating X axis. This motion permits the grating Z axis to be brought into coincidence with the grating mount azimuth rotation axis so that "rocking" of the grating mount will result in "rocking" of the grating about its Z axis.

The lower base plate is attached to the grating drive arm plate (5.05.07). This plate has two arms used to position the grating normal to the required normal incidence and grazing incidence azimuths. Short, pointed 0.250" steel pins are pressed into holes near the end of each arm. These pins are connected to the azimuth drive mechanism by a short removable link.

As shown in section 5.01.02, the grating must rotate approximately five degrees in a twenty minute period. Using a 0.05 cm/turn micrometer thread driven by a one RPM sychronous motor to supply linear motion for the drive arm (5.05.07) gives a travel of one centimeter in twenty minutes. Hence, a drive arm length of 11.45 cm or 4.51 inches is required to give the desired azimuth rotation rate.

A complete scan of the zero to 2969 Å spectrum requires rotation of the grating normal from the instrument centerline to an angle of 7.5 degrees with the centerline in the direction of the light source. In order to achieve a reasonably constant angular scan rate over the full range, it is desirable that the drive arm move equal distances on both sides of the instrument centerline. Hence, the angle of rotation to either side of the centerline is 3.75 degrees. As the extreme CCW position of the grating places the normal along the centerline, an arm angle of 3.75 degrees CCW from the normal is desirable.

At the scan rate of 0.25°/rev., the drive screw must turn through $7.5^\circ/0.25^\circ$/rev. or 30 revolutions. The drive screw pitch is 0.05 cm/turn. Hence, the total drive nut advance is 1.5 cm.

From section 4.06.04, the grating normal for grazing incidence is set at an angle of 77 degrees with the instrument centerline. Hence, the arm position for the grazing incidence setting is 77 degrees CW from the normal. This places the arm along the centerline for grazing incidence use.

A flange (5.05.05) is soldered to the bottom side of the arm plate. This flange mates with a bearing (5.05.08S) recessed into the base plate (5.06.01).

5.02.06: Base Plate

The entire grating mount is constructed on an aluminum base plate. This plate has a recess hole at the grating center to receive the bearing (5.05.08S). At the center of this bore is a 0.250" alignment hole. This hole and a second alignment hole at (4.00.00, 1.00.00) provide positive alignment of the grating mount to the spectrograph mounting plate. At the rear of the base, a marker provides a coarse indication of correct alignment of the grating mount and the drive unit outside of the vacuum chamber.

5.02.07: Drive Mechanism

A 0.05 cm/turn micrometer screw (5.03.05) restrained from axial motion by a shaft guide (5.06.03) rigidly attached to the base plate (5.06.01) drives the traveling assembly (5.03.01) along a set of ways formed by a guide plate (5.03.02) and a pair of guide bars (5.03.03-2). These ways prevent lateral motion of the traveling assembly that might be caused by drive screw wobble. The traveling assembly motion is transmitted from the pin (5.03.01C) in the traveling assembly to the drive arm pin by a coupling link (5.03.06). (An unsatisfactory system having the micrometer nut mounted on the drive arm was used in the original design. This was fabricated and is described in section 14.01.00.)

Power is transmitted to the drive screw from the drive shaft assembly (5.08.00). This shaft has a keyed flange designed to mate with the flange (5.03.08) on the drive screw shaft (5.03.04). The drive shaft is locked to the flange by a 1/16" key (5.03.10S) through one of the coupling pins.

5.03.00: Grating Drive Unit Description

5.03.01: Complete Drive Unit

The complete drive unit is shown in figure 5.03.01 A and by assembly drawings 5.07.00-B, C and E (figures 5.03.01-B, C and D). This unit supports the grating drive motor and transmits driving torque to the grating drive mechanism inside the vacuum chamber. This unit provides an indicator for determining the grating normal azimuth. It also provides limit switches to stop the drive motor. A switch is provided for operating the motor at the drive unit as well as at the remote control unit (5.09.00).

5.03.02: Motor Mount

The drive motor is mounted on plate 5.07.14 and coupled to the 0.250 inch shaft (5.07.19S) running through the unit. The motor is covered by a 6 x 6 x 6 inch steel box (4.07.02S) that is bolted to the mounting flange (5.07.14).

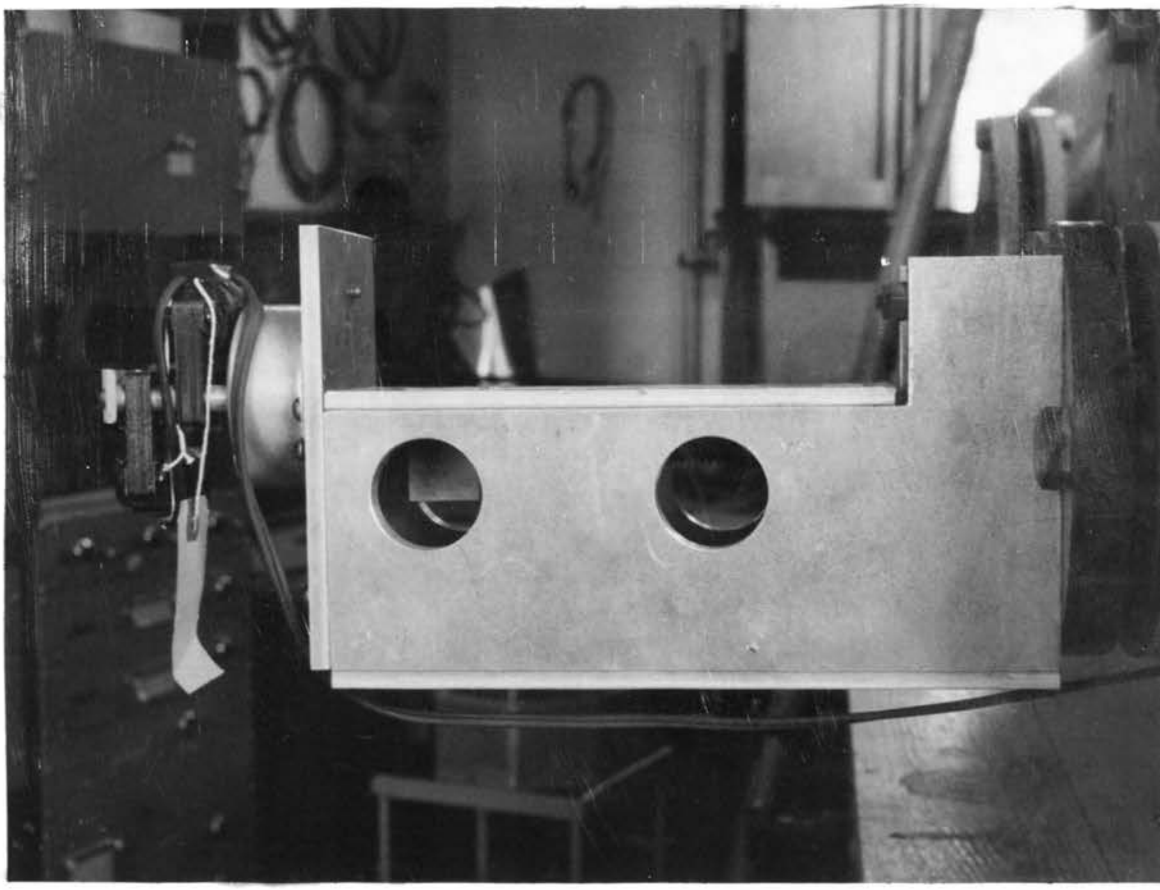


Figure 5.03.01A: Grating Drive Unit Installed on Spectrograph

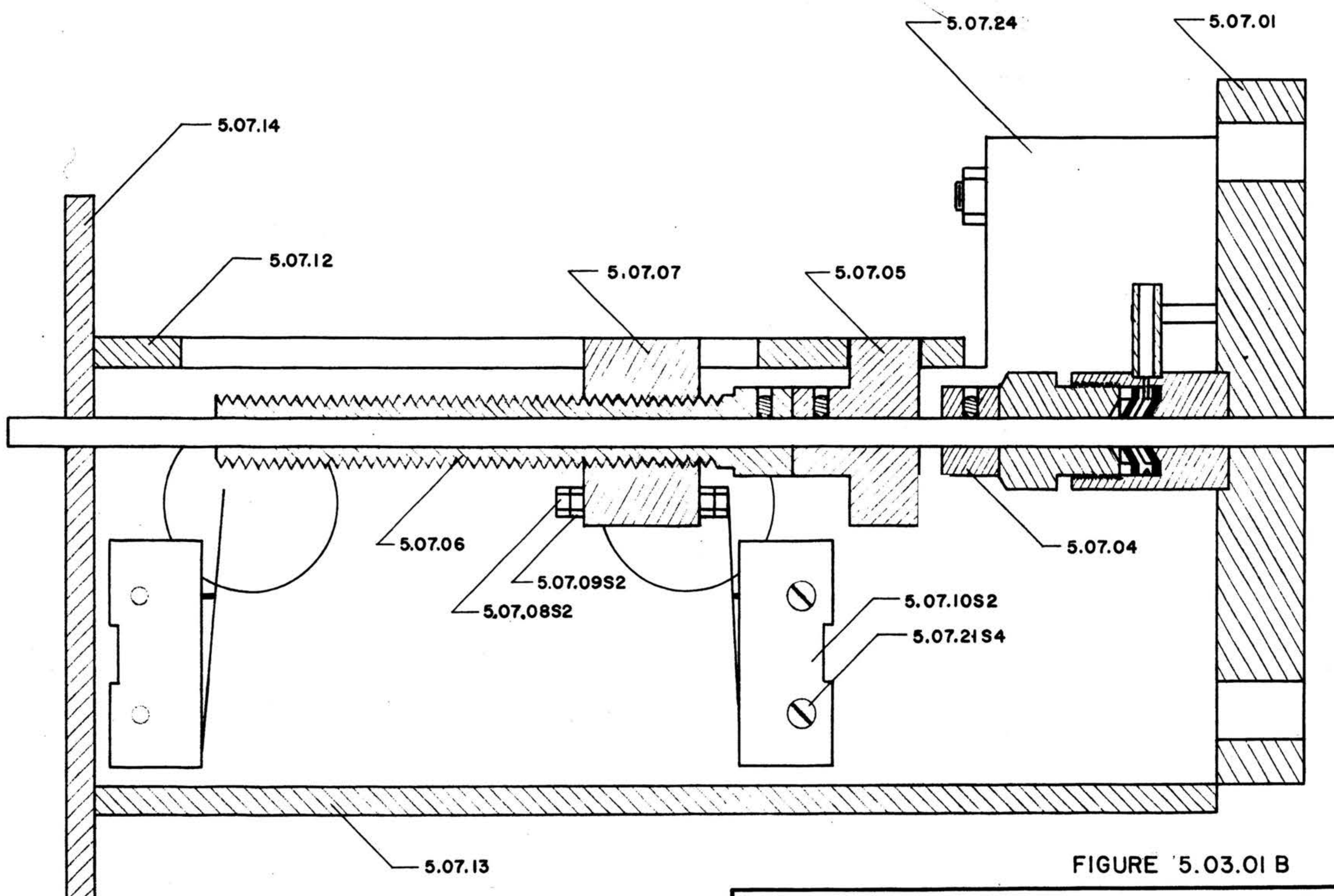
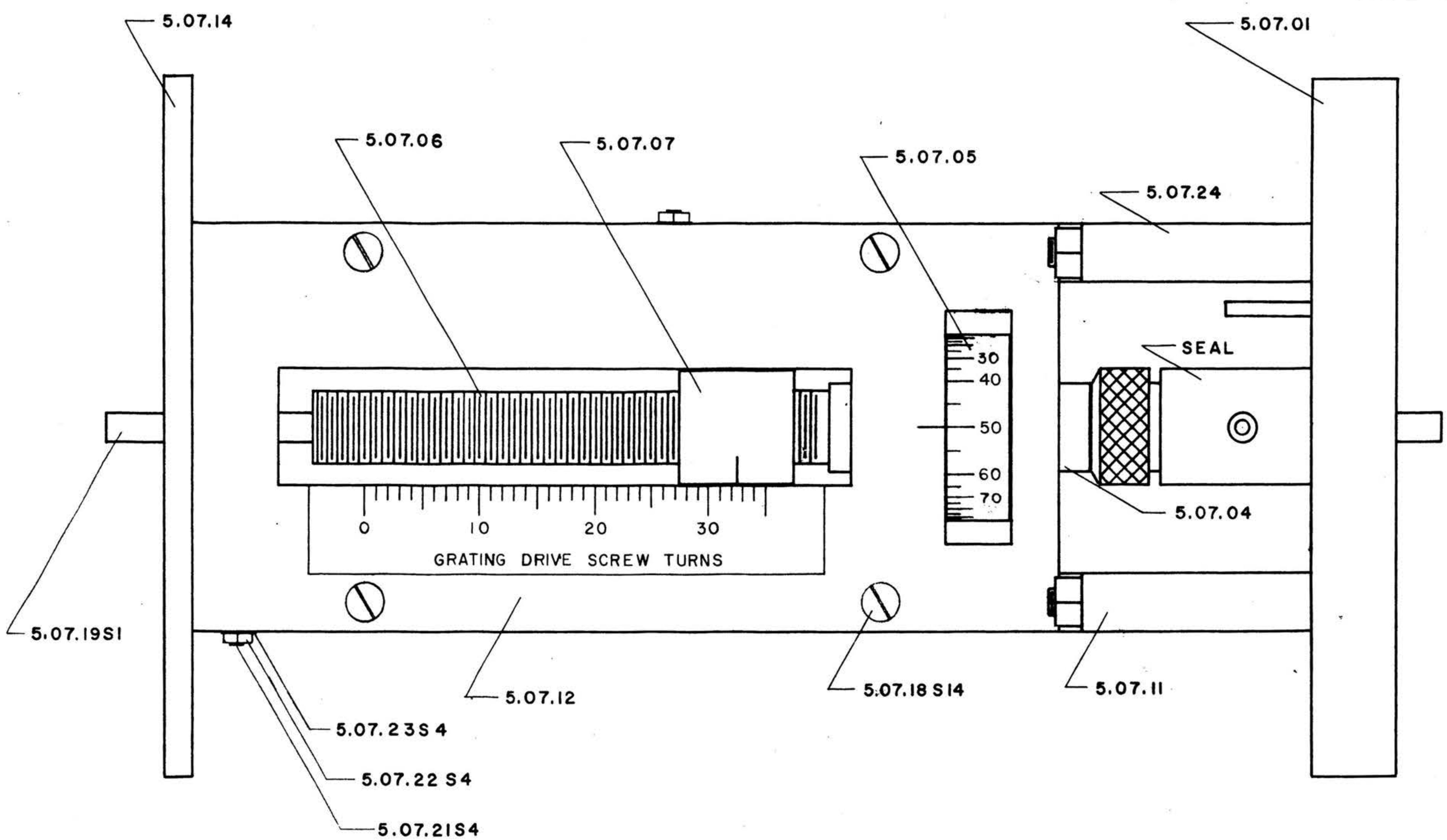


FIGURE 5.03.01 B

— SIDE VIEW —
CROSS-SECTIONAL VIEW THROUGH CENTER
FULL SCALE

M.S.M. PHYSICS DEPT.		
VACUUM SPECTROGRAPH		
11/20/56	GRATING DRIVE UNIT	
J.K.H.	5.07.00	DWG. 5.07.00-B



— TOP VIEW —
FULL SCALE

FIGURE 5.03.01 C

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
11/27/56	GRATING DRIVE UNIT
J.K.H.	5.07.00 DWG. 5.07.00-C

DWG. SHOWS END VIEW WITH MOTOR MOUNT BOARD REMOVED.

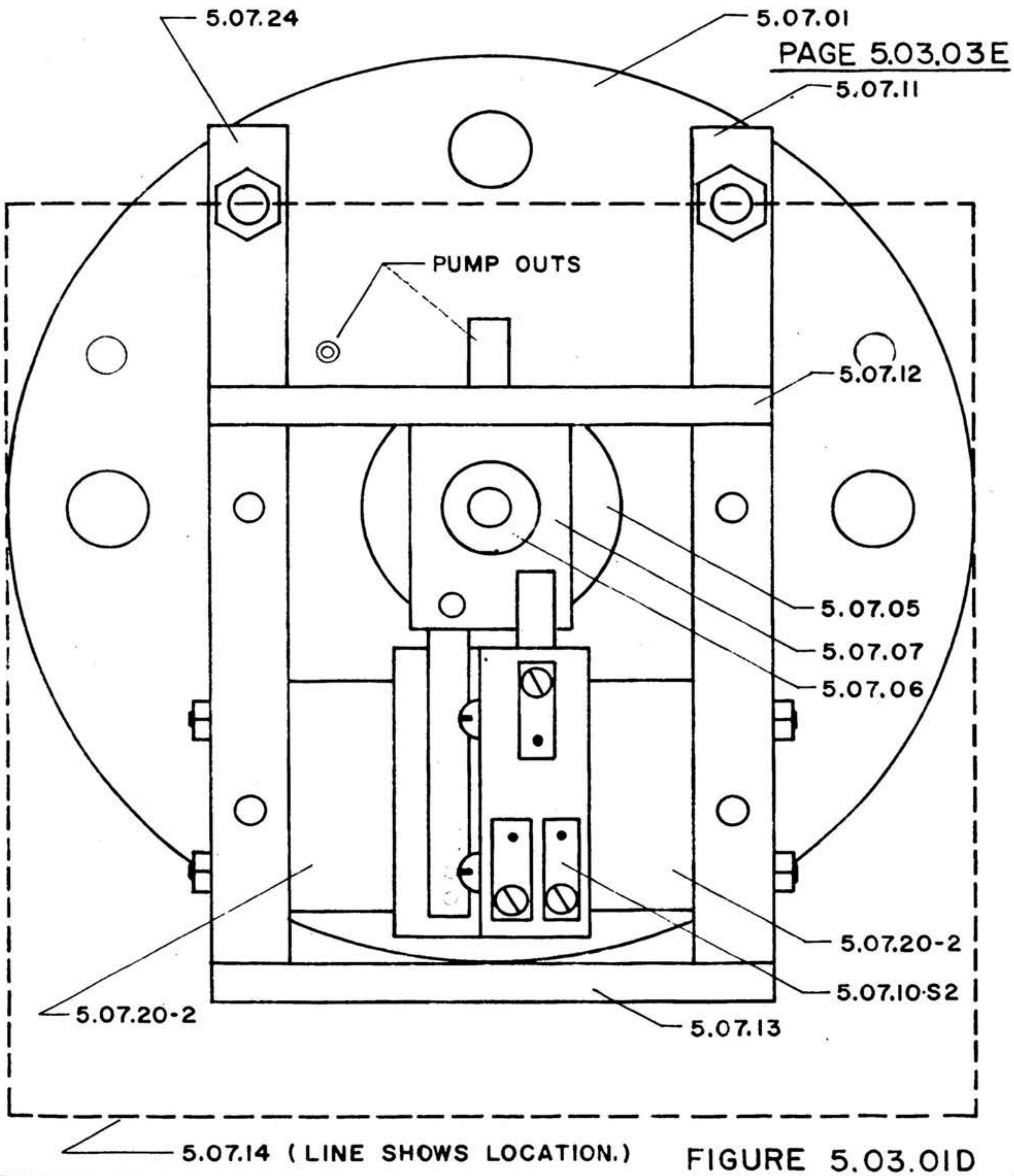


FIGURE 5.03.01D

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
11/22/56	GRATING DRIVE UNIT
J.K.H.	5.07.00 | DWG. 5.07.00-E

5.03.03: Grating Position Indicator

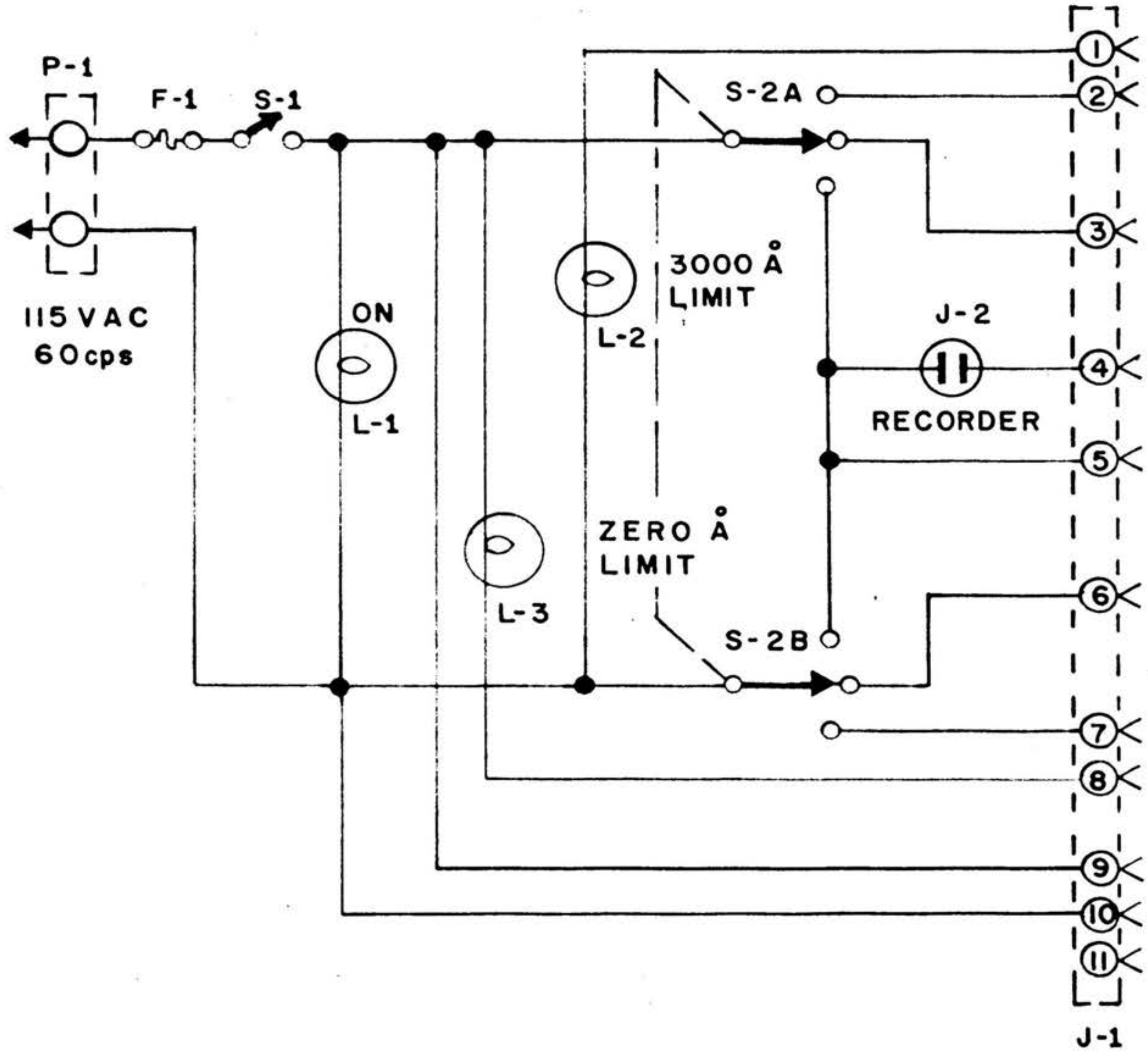
The grating normal position is indicated by the coarse and fine scales on the drive unit. The coarse indication is provided by a counter block (5.07.07) that moves one division on the coarse scale for each turn of the drive shaft and drive screw (5.07.06). The fine indication is provided by a 100 division scale wheel (5.07.05) that turns with the drive shaft.

5.03.04: Vacuum Seals

The driving power is transmitted to the inside of the vacuum chamber by a 0.250 inch polished steel shaft that passes through a Wilson seal (5.07.01). A self centering double "O" ring seal (8.03.07S) is used between the drive unit and the vacuum chamber flange. Pump outs are provided between both the "O" rings and the Wilson seal washers.

5.03.05: Limit Action and Electrical Circuit

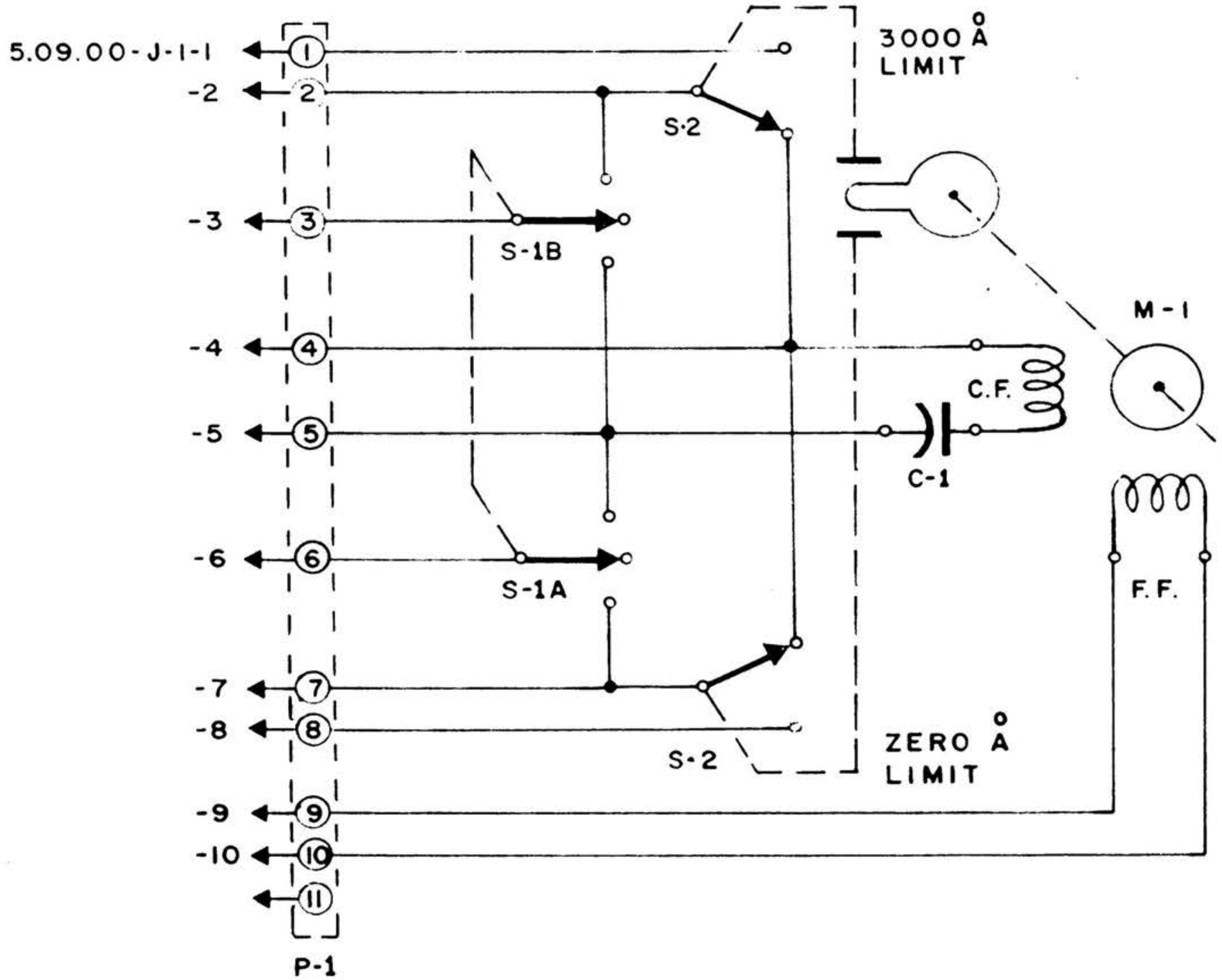
Limit switches S1 and S2 (see figure 5.03.05A) actuated by the counter block at each end of its travel prevent the grating mount from being driven into its mechanical limits. The drive motor may be operated either from switch S-1 (see figure 5.03.05A) on the motor mount plate or from the Control Unit (5.09.00). The complete electrical circuit for the drive unit is shown by figure 5.03.05A (drawing 5.07.00H).



ELECTRICAL SCHEMATIC

FIG. 5.05.00-B

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	GRATING DRIVE CONTROL UNIT
	DWG. 5.09.00 H



ELECTRICAL SCHEMATIC
FIG. 5.03.05 -A

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	GRATING DRIVE UNIT
	DWG. 5.07.00 H

5.04.00: Grating Drive Shaft Description

The grating drive shaft assembly (5.08.00) couples the drive unit to the grating mount. This assembly is shown in figure 5.04.00A (Assembly drawing 5.08.00).

Minature universal joints at each end allow slight miss-alignment between the drive unit and the grating mount drive shafts. In order that the shaft may be pushed back out of the way when either the grating mount or the mounting platform is being removed from the vacuum chamber, the shaft length is variable. Part 5.08.07 may be moved in and out on rods 5.08.08. This arrangement gives variable shaft length but negligible backlash.

The coupling flange (5.08.04) has two index pins (5.08.01 and 5.08.02) protruding from its face that fit into matching holes in the grating mount flange to transmit the driving torque. This arrangement allows disconnection from the grating mount without loss of drive unit scale calibration.

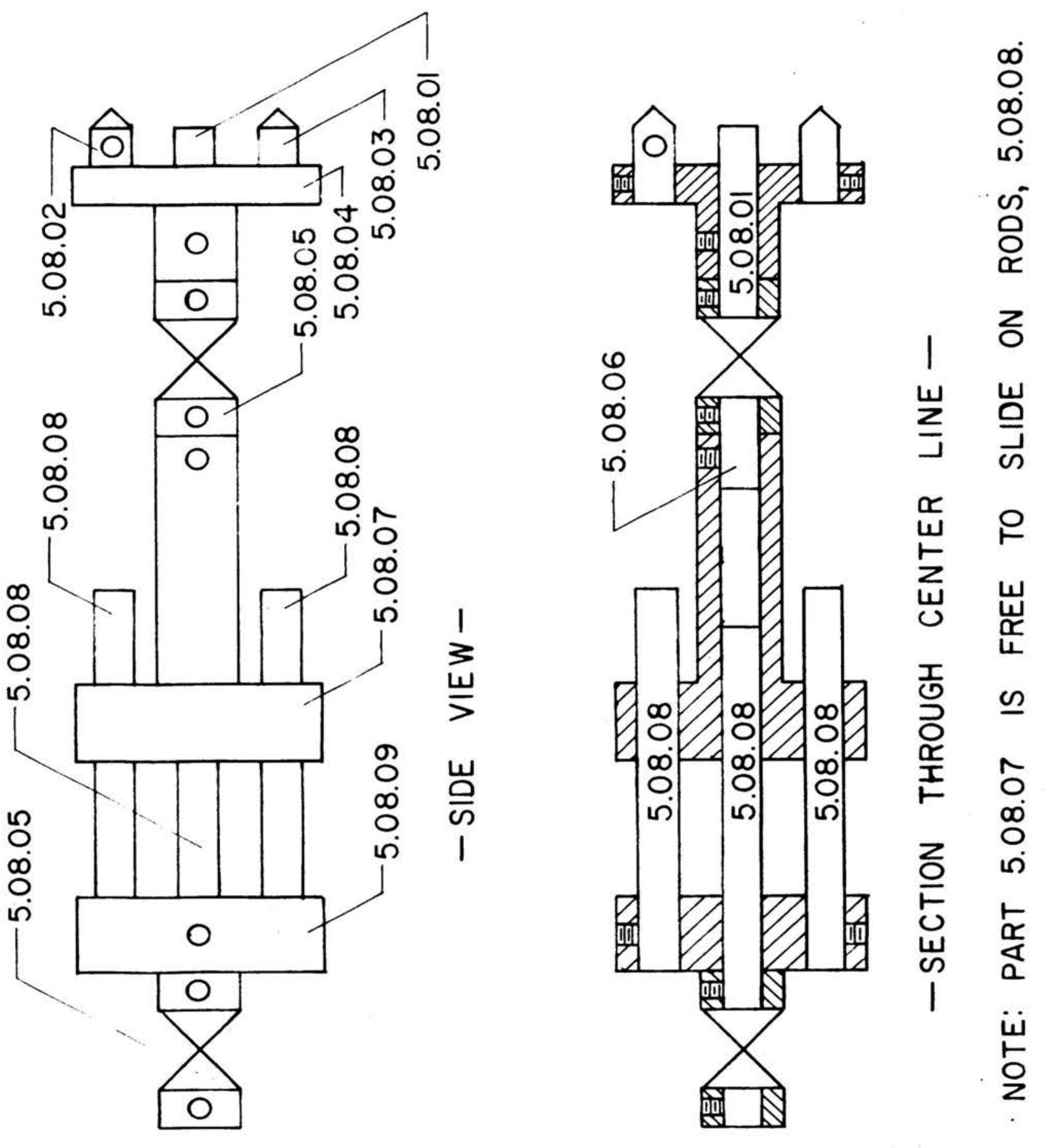


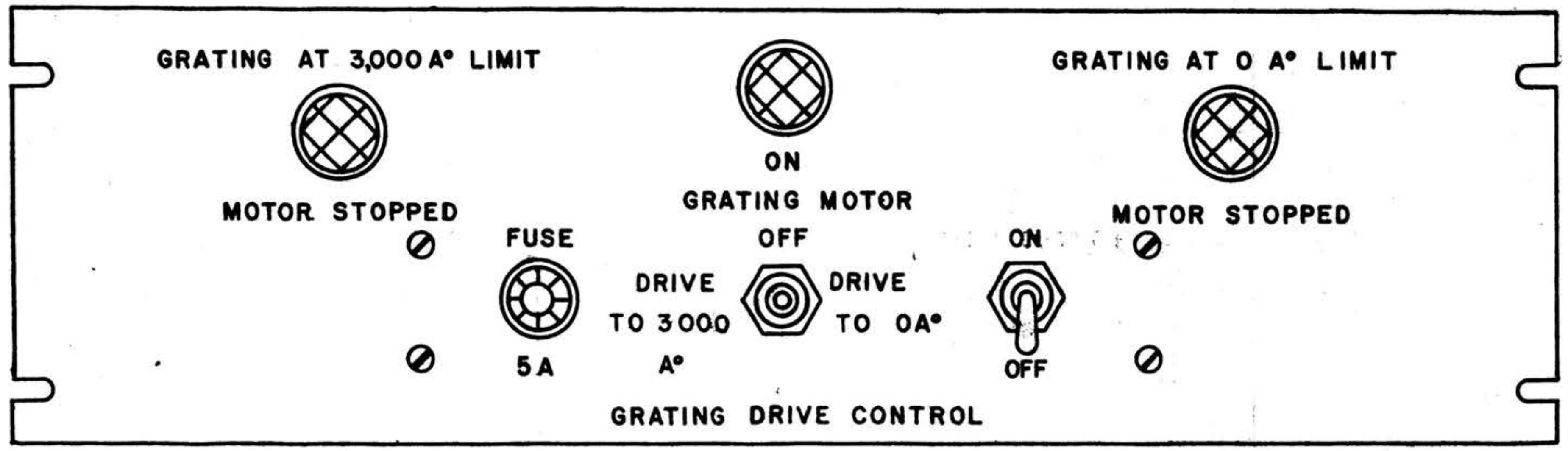
FIGURE 5.04.00 A

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
J.K.H. 5/27/57	GRATING DRIVE SHAFT ASS'Y.
ASS'Y. No. 5.08.00	DWG. No. 5.08.00-B

5.05.00: Grating Drive Control Unit Description

The grating drive motor is controlled from the rack mounted Grating Drive Control Unit (5.09.00). This unit is shown in figure 5.05.00A (Drawings 5.09.00B and 5.09.00F). The electrical circuit is shown by figure 5.05.00B (drawing 5.09.00H).

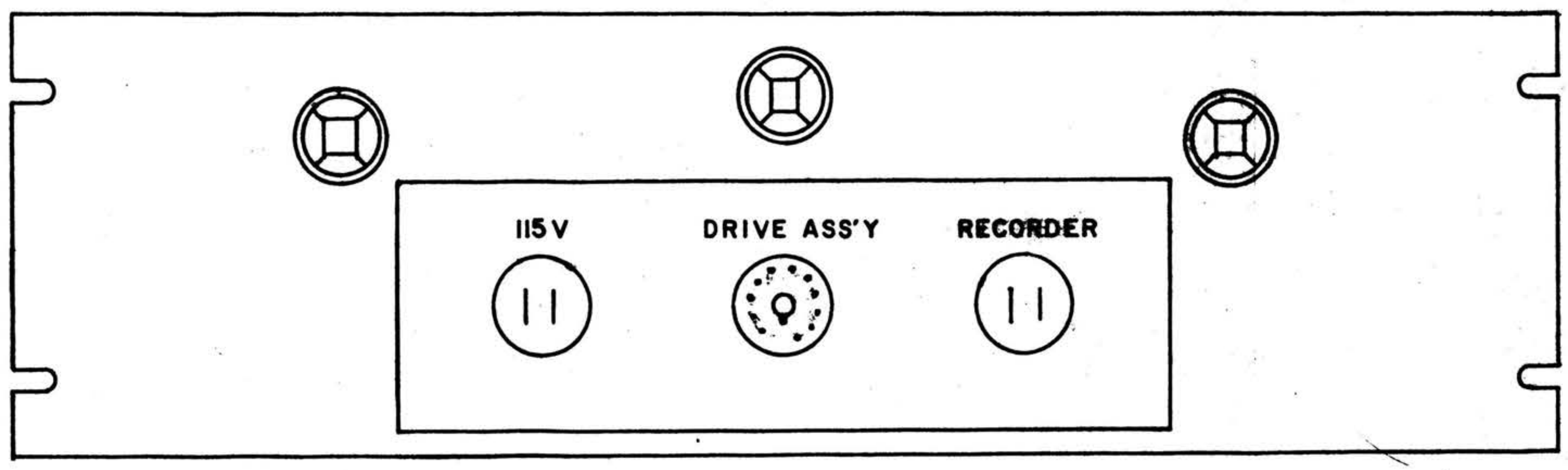
This unit contains a drive unit master power switch (S1), fuse and a three way switch (S2) used to run the drive motor toward either the zero or 3,000 Å limits. Placing the control switch in the off (center) position allows control by switch S-2 (see figure 5.03.05A) at the drive unit. Excitation of the drive motor control field by either switch energizes a 115 volt outlet (J-3) at the rear of the panel. This power may be used to start recording equipment when the grating scan begins. Lights L2 and L3 provide indication that a limit has been reached and that the motor has stopped.



FRONT VIEW

DWG NO. 5.09.00B

FIG. 5.05.00-A



REAR VIEW

DWG NO. 5.09.00F

HALF SCALE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/31/56	GRATING DRIVE CONTROL
DRAWN BY: D.D.H.	UNIT NO. 5.09.00

5.06.00: Adjustment and Installation

5.06.01: Installation

The grating mount is installed on the grating end mounting plate (7.02.01) so that the 0.25 inch hole at the center of the azimuth bearing is concentric with the 0.25 inch hole in the mounting plate at (0, 0). A 0.250 inch steel dowel pin (5.06.06-S2) is inserted through these holes to secure the alignment. The grating mount base is then secured to the mounting plate by four 10-24 cap screws (5.06.07S4) at (2,1), (2,-4), (-2,1) and (-2,-4). With the mounting base plate (5.06.01) aligned and screwed down securely, a 0.250 inch hole is drilled through the base plate through the alignment hole at (4,1) and an alignment pin (5.06.06S2) is inserted. The two pins maintain alignment from that point on, allowing the mount to be removed from and replaced on the plate without loss of initial alignment.

The grating drive shaft assembly (5.08.00) is attached to the grating drive unit shaft (5.07.19S1) and the set screws in the universal joint are tightened. The drive unit (5.07.00) is then bolted in place at the end of the two inch side port at station line 4.500 with four cap screws (8.03.01) and nuts (8.03.02). A self-centering (8.04.01) seal is used between flange 5.07.01 and the flange on the vacuum chamber. After the drive unit is bolted in place, concentric 0.250 inch holes are drilled through flange 5.07.01 and the vacuum chamber flange at the points indicated by (B) in drawing 5.07.01. One inch, 0.250 inch diameter steel dowel pins are inserted to hold the alignment.

Connection of the drive shaft to the grating mount is described in 5.05.02.

5.06.02: Azimuth Alignment-Normal Incidence

At the time of the initial installation and alignment, the drive nut (5.03.01-A) is driven to a point such that the grating normal is along the spectrograph centerline as shown in Figure 5.02.01B. At this time a scribe mark is made at the back edge of the drive arm plate (5.05.07) to coincide with the mark at the center of the marker (5.06.02). The drive shaft (5.07.19S1) is turned so that its scales read 2.000. With the grating shaft assembly (5.08.00) securely locked to the drive shaft (5.07.19S1) by the set screws in the universal joint at the drive unit end, the two set screws (5.08.10S7) in coupling flange 5.08.04 are loosened to allow rotation of the flange on shaft 5.08.01. The flange is rotated to the position so that it will mate correctly with flange 5.03.08 on the grating mount. The key (5.03.10S1) is inserted and flange 5.08.04 is locked to shaft 5.08.01 with the set screws.

After the preceding alignment has been made, the grating mount may be removed and replaced in the vacuum chamber without loss of azimuth alignment. Upon re-installation, it is necessary only to return the counter and the drive arm scribe mark to these same positions before mating the 5.08.04 and 5.03.08 flanges. When the grating mount is removed, flange

5.08.04 on the drive shaft is pushed back into the drive tube and out of the way.

After installation and alignment to the drive unit, the grating normal may be pointed to any desired azimuth by rotating the drive unit drive shaft to the desired setting. Once the correct scale reading is determined, a setting may be repeated by returning to that scale setting. In order to minimize backlash errors, the desired setting should always be approached from the direction of the zero scale reading. This method for returning the grating normal to a desired azimuth may be used for both normal and grazing incidence.

5.06.03: Azimuth Adjustment-Grazing Incidence

The grating mount is set up for grazing incidence use by lifting the coupling link (5.03.06), lifting the azimuth rotating portion of the mount slightly and rotating it in a counter-clockwise direction until the grazing incidence arm can be coupled to the drive mechanism by the drive link. (Care must be used in lifting the rotating portion of the grating mount in order to avoid disturbing its adjustment).

The desired grazing incidence normal azimuth angle of 77 degrees is obtained by rotating the drive shaft (5.07.19S1). Once the correct angle is determined, the drive unit scale reading is recorded and future adjustments are made by returning to this setting. To facilitate removal and replacement of the mount when it is being used for grazing incidence, a second scribe mark is used on the drive arm plate to coincide with the marker when the grating is positioned for grazing incidence.

5.06.04: X Axis Adjustment-Rotation

The grating may be rotated about its X axis 180 degrees by backing off thumbscrews 5.02.04-2 and rotating the holder. Fine X axis adjustments are made by turning the thumbscrews together until the rulled lines are vertical. The lines are aligned to a vertical and not to one of the entrance slits!

5.06.05: X Axis Adjustment-Translation

The grating is moved along its X axis until the center of its face is on the azimuth rotation axis of the grating mount (Grating Z axis coincident with mount azimuth rotation axis). This adjustment is made by turning thumbscrew 5.05.04 at the rear of the mount. (See figure 5.02.01D) This adjustment is locked by tightening two set screws (5.05.15S7) in the top side of the rear guide plate (5.05.09).

5.06.06: Y Axis Adjustment

The grating is adjusted about its Y axis so that the rulings are vertical by turning thumbscrew 5.04.05 at the back of the mount. (See figure 5.02.01D)

5.07.00: Construction

All detailed information required for part fabrication and assembly of the grating mount and its supporting units is given by the series 5.00.00 drawings at the end of this section. Some of the assembly drawings are used as illustrations elsewhere in this thesis. These drawings are:

	5.00.00-B, C, E & F	(See figures 5.02.01-A, B, C & D),
	5.07.00-B, C & E	(See figures 5.03.01-B, C & D),
	5.07.00-H	(See figure 5.03.05A),
	5.08.00-B	(See figure 5.04.00A)
and	5.09.00-B, F & H	(See figures 5.05.00 A & B).

Drawing 5.00.00-A Sheet 1 of 1
Grating Mount & Drive Assemblies
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y. No:	Dwg. No:	Note:	Description:
5.00.00	5.00.00-A		Grating Mount, Drive
	5.00.00-B	A	Assemblies & Control Box
	5.00.00-C	A	
	5.00.00-E	A	(Dwgs. B, C, E & F show
	5.00.00-F	A	grating mount only.)
5.01.00	5.01.00-A		Grating Holder
5.02.00	5.02.00-A		Grating Holder Bracket
5.03.00	5.03.00-A		Drive Ass'y.-Base Mtd.
5.04.00	5.04.00-A		Upright Ass'y.
5.05.00	5.05.00-A		Lower Base Ass'y.
5.06.00	5.06.00-A		Grating Mount Base Ass'y.
5.07.00	5.07.00-A		Grating Drive Unit
5.08.00	5.08.00-A		Grating Drive Shaft
5.09.00	5.09.00-A		Grating Drive Control

ASSEMBLY NOTES:

(A)

Assembly grating mount as indicated in these drawings and the applicable sub-assembly notes..

Drawing 5.01.00-A
Grating Holder Assembly
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.01.00	5.01.00-A	A	Grating Holder Ass'y.
5.01.01	5.01.01		Grating Holder
5.01.02	5.01.02 5.06.02		Grating Retainer
5.01.03	None		Grating
5.01.04	None	1	Nut-Mod. 3/8" N.C. Hex.
5.01.05S2	None		Grating Retainer Screws. 1/2", 6-32 round Head, brass.
5.01.06S2	None	2	Washer, 3/8", 1/16", brass.
5.01.07S1	None		Set Screw, 1/8", 6-32, Allen, Steel.

FABRICATION NOTES:

(1)

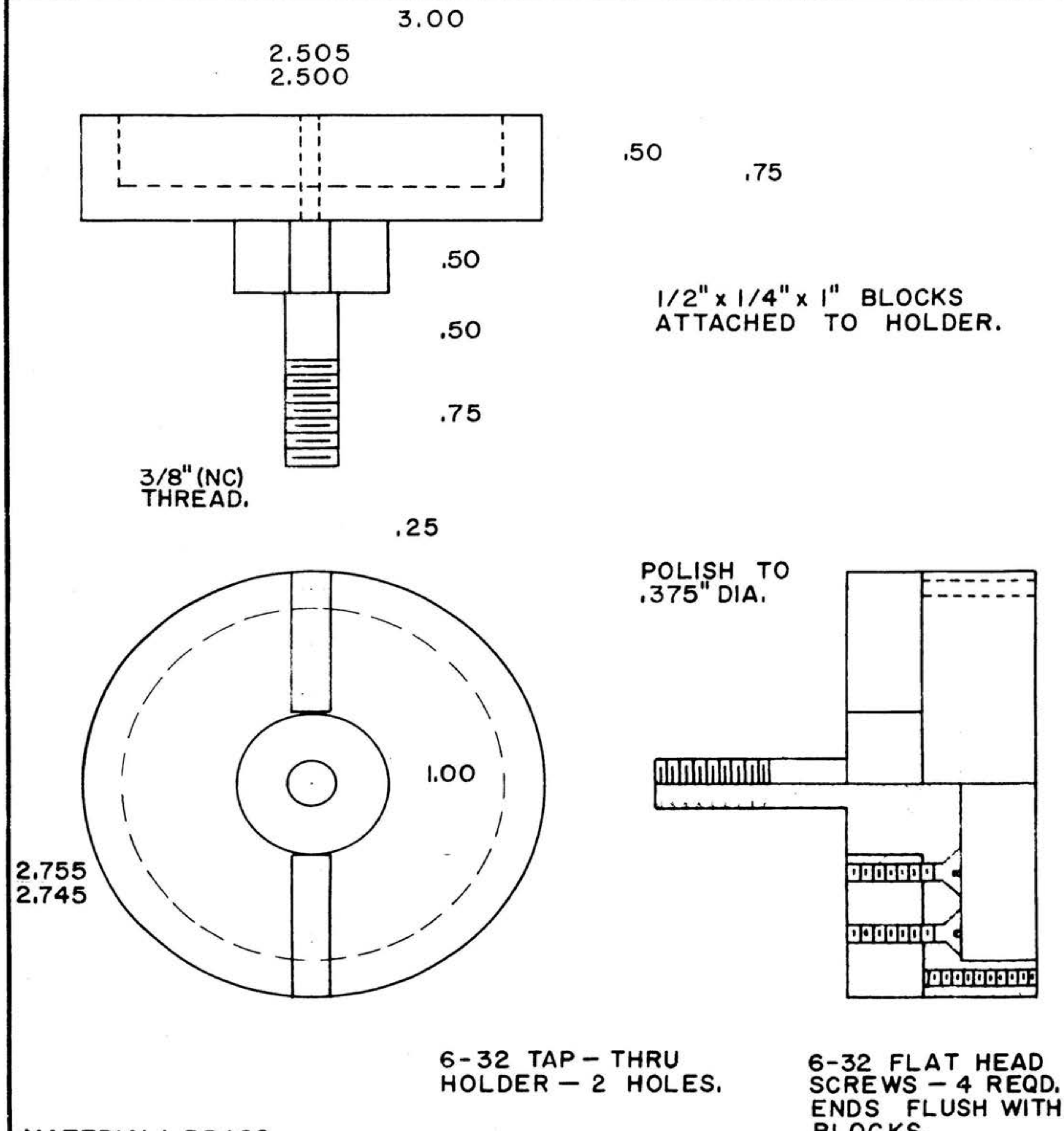
Modify a 3/8" hex, N.C. nut by equipping with a 1/8", 6-32 Allen set screw (P/N 5.01.07.S) at the center of one face. (see dwg. 5.00.00-C)

(2) Washers must have flat, parallel surfaces.

ASSEMBLY NOTES:

(A) Install washers 5.01.06S2 on each side of the cross arm (5.02.01). Turn nut 5.01.04 until play between grating holder and cross arm is eliminated but holder may be freely rotated. Lock nut 5.01.04 to holder shaft 5.01.01 with set screw 5.01.07S1.

Mount grating in recess in holder 5.01.01 and install retainer 5.01.02 to hold the grating in place. Use screws 5.01.05S2.

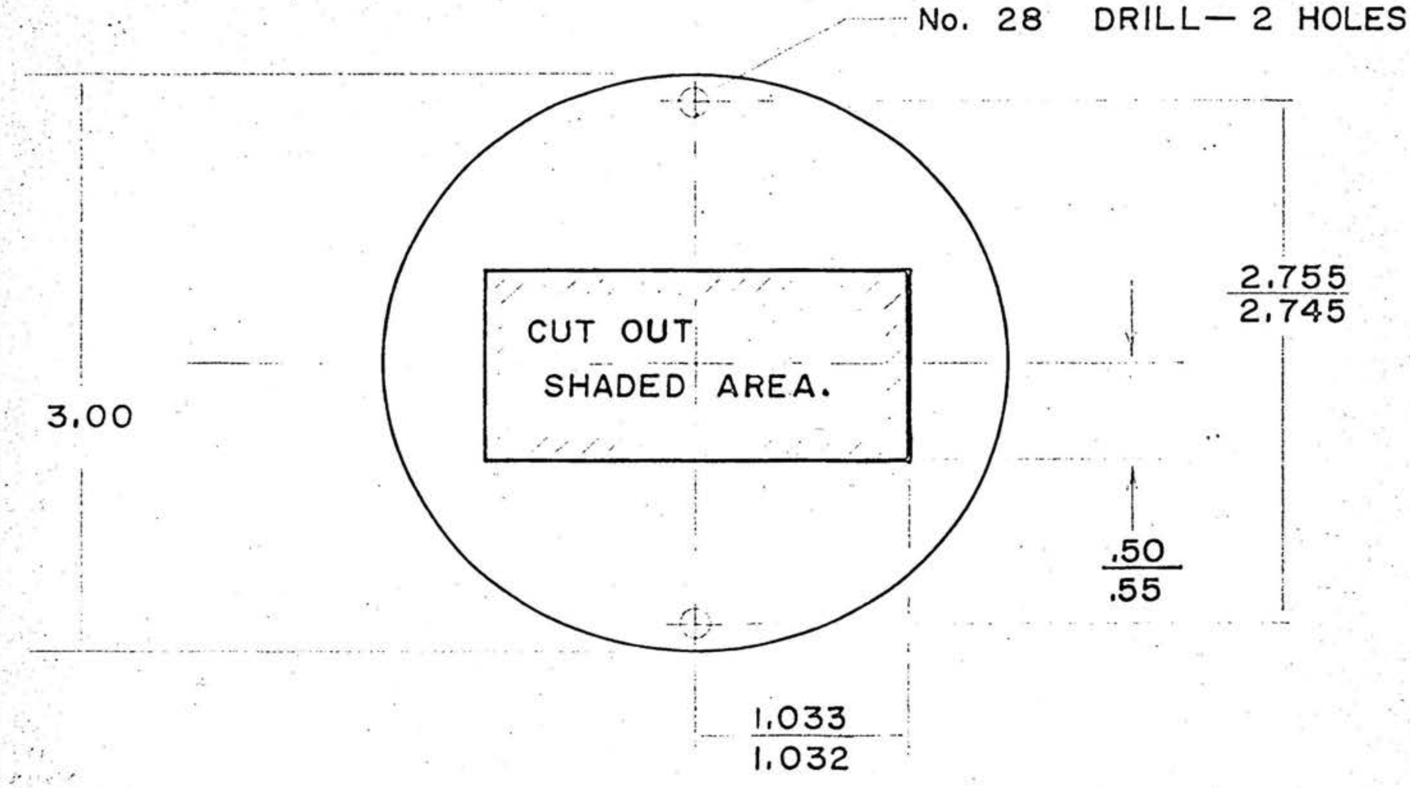


MATERIAL: BRASS

M.S.M. PHYSICS DEPT.

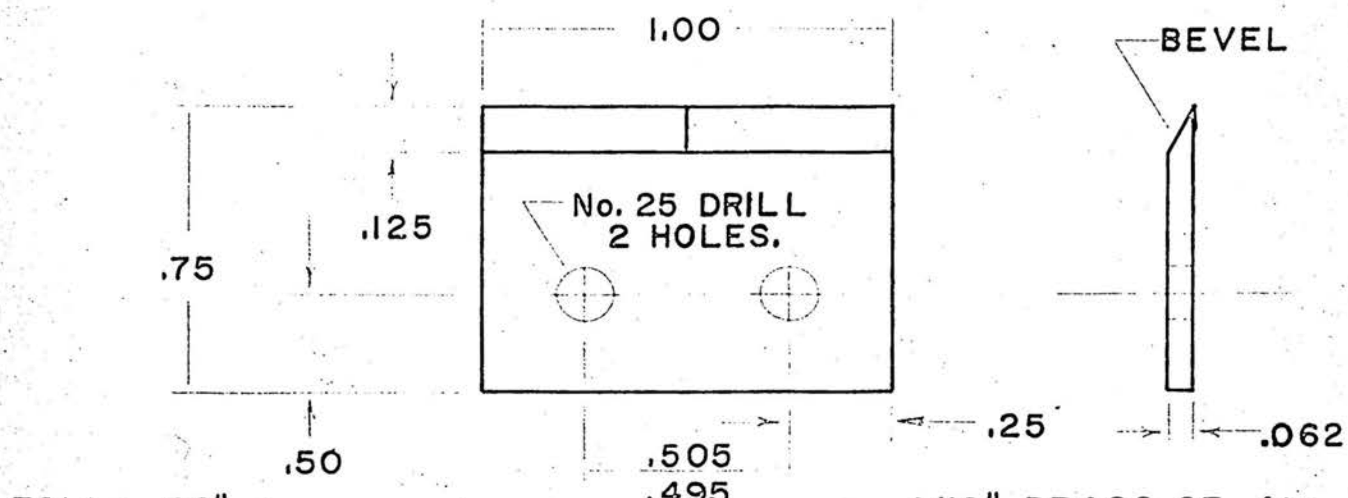
VACUUM SPECTROGRAPH

JKH – 6/21/56	GRATING HOLDER
	PART No. 5.01.01



MATERIAL: 1/16" AL.

GRATING RETAINER	5.01.02



TOL: ± .02"

1/16" BRASS OR AL.

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

JKH 6/25/56	MARKER
	5.06.02

Drawing 5.02.00-A
Grating Holder Bracket
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.02.00	5.02.00-A	A	Grating Holder Bracket
5.02.01	5.02.01	1	Cross Arm
5.02.02	5.02.02	1	Grating Holder Arm-R
5.02.03	5.02.03	1	Grating Holder Arm-L
5.02.04-2	5.02.04-2 5.04.05 5.04.03		Set Screw
5.02.05S4	None		Screw, flat heat, 3/4", 10-24, brass.
5.02.06	None		P/N not used.
5.02.07S2	None		Washer, brass, 1/4", 1/8" thick
5.02.08	None		P/N not used.
5.02.09S2	None		Shaft, 3/4", 0.250" dia. polished steel drill rod.

FABRICATION NOTES:

(1)

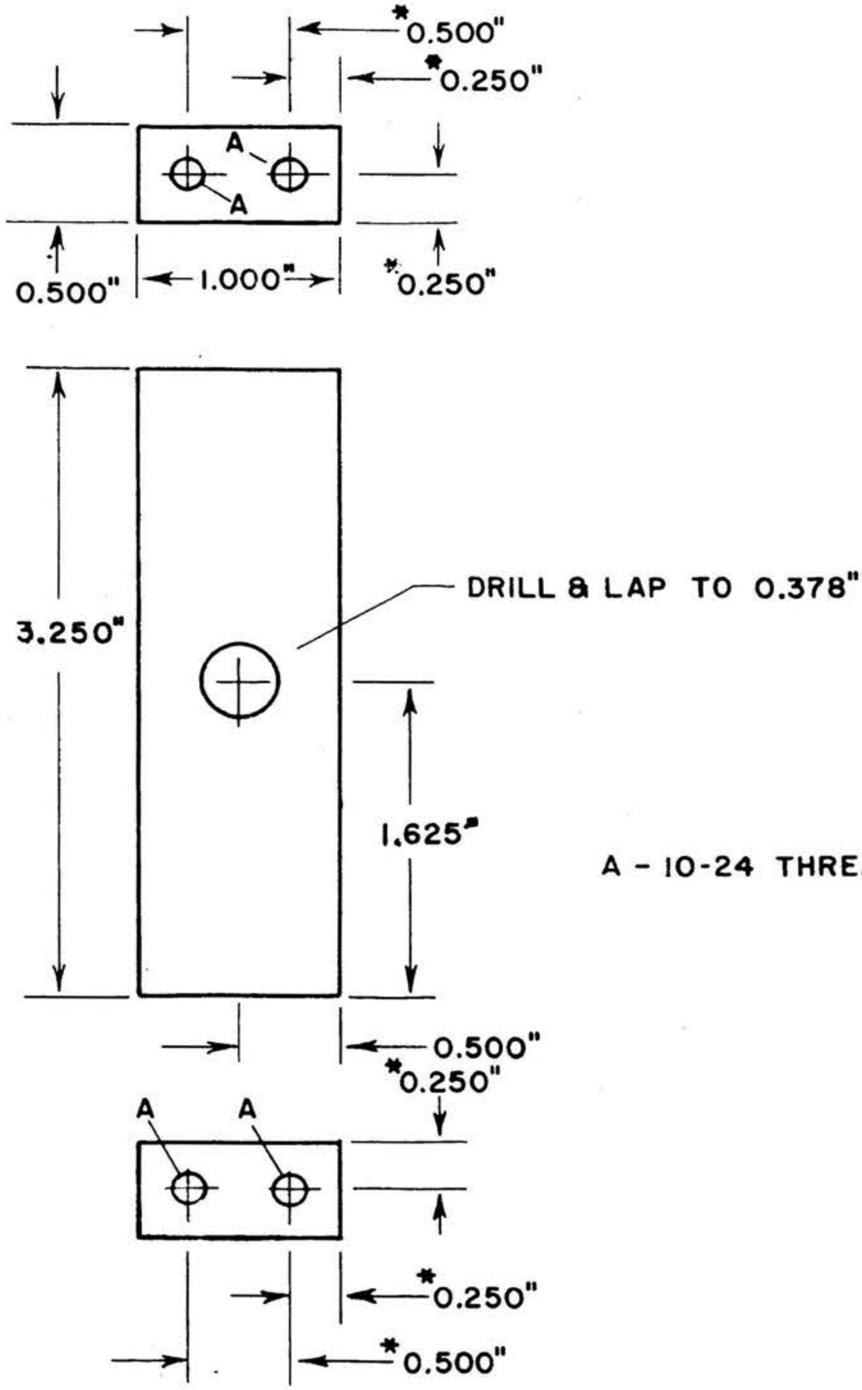
These parts must be capable of meeting the requirements of assembly note (A).

ASSEMBLY NOTES:

(A)

Fit cross arm 5.02.01 to grating holder arms 5.02.02 and 5.02.03 so that when screws 5.02.05S4 are tightened, a 0.250" polished steel drill rod may be inserted through both holes in the holder arms when the grating holder (5.01.01) is removed.

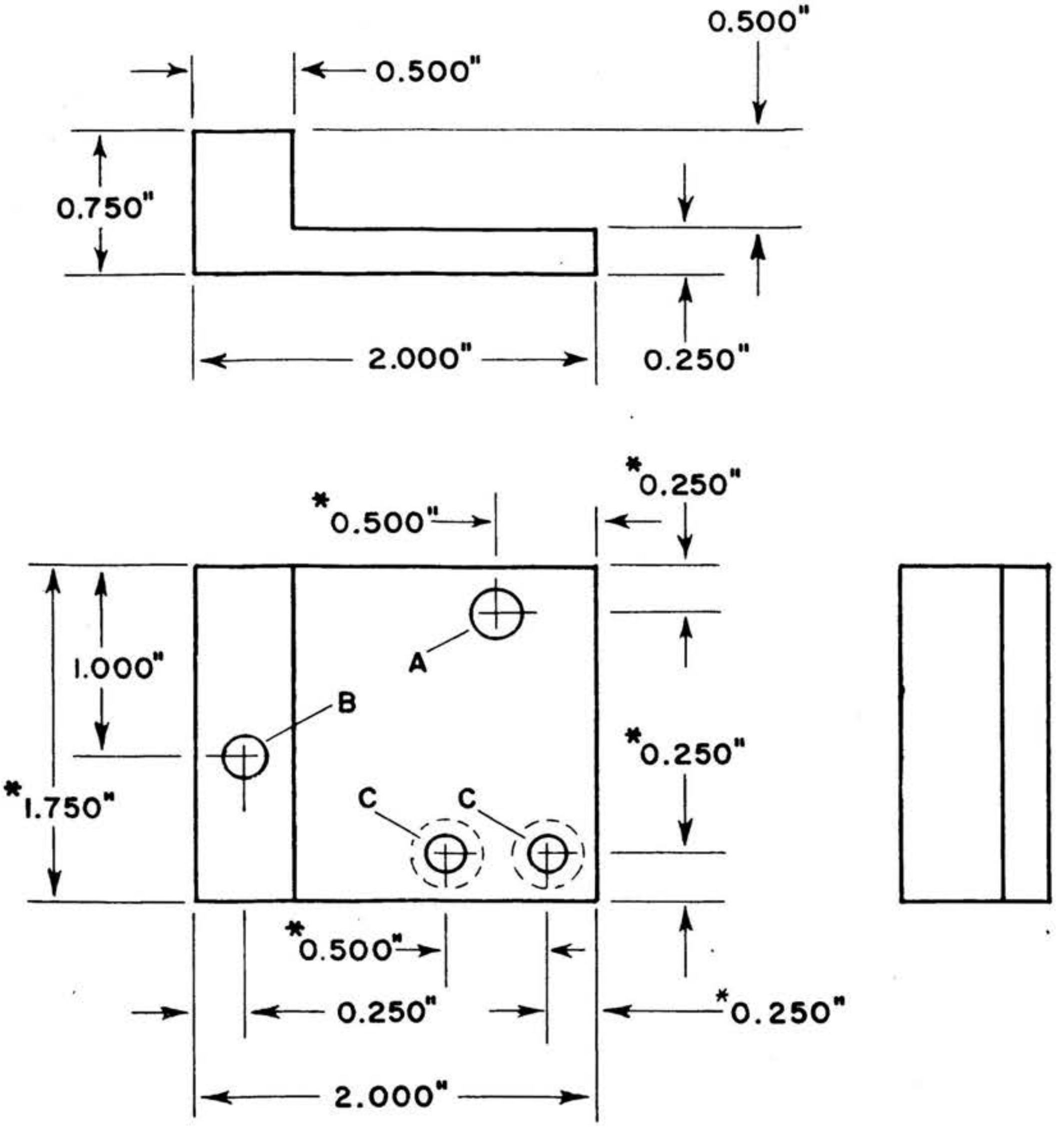
After assembly of parts 5.02.01, 5.02.02 and 5.02.03, install shafts 5.02.09S2 in the 0.250" holes in 5.02.02 and 5.02.03 so that their ends are flush with the inside of the bracket. See dwg. 5.00.00-B. Thread adjustment screws 5.02.04-2 into the holder arms.



A - 10-24 THREADS, 0.6" DEEP.

* TOL- 0.015" -(* DENOTES ±0.005")
MATERIAL - YELLOW BRASS OR 2024 T4 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	CROSS ARM
	5.02.01

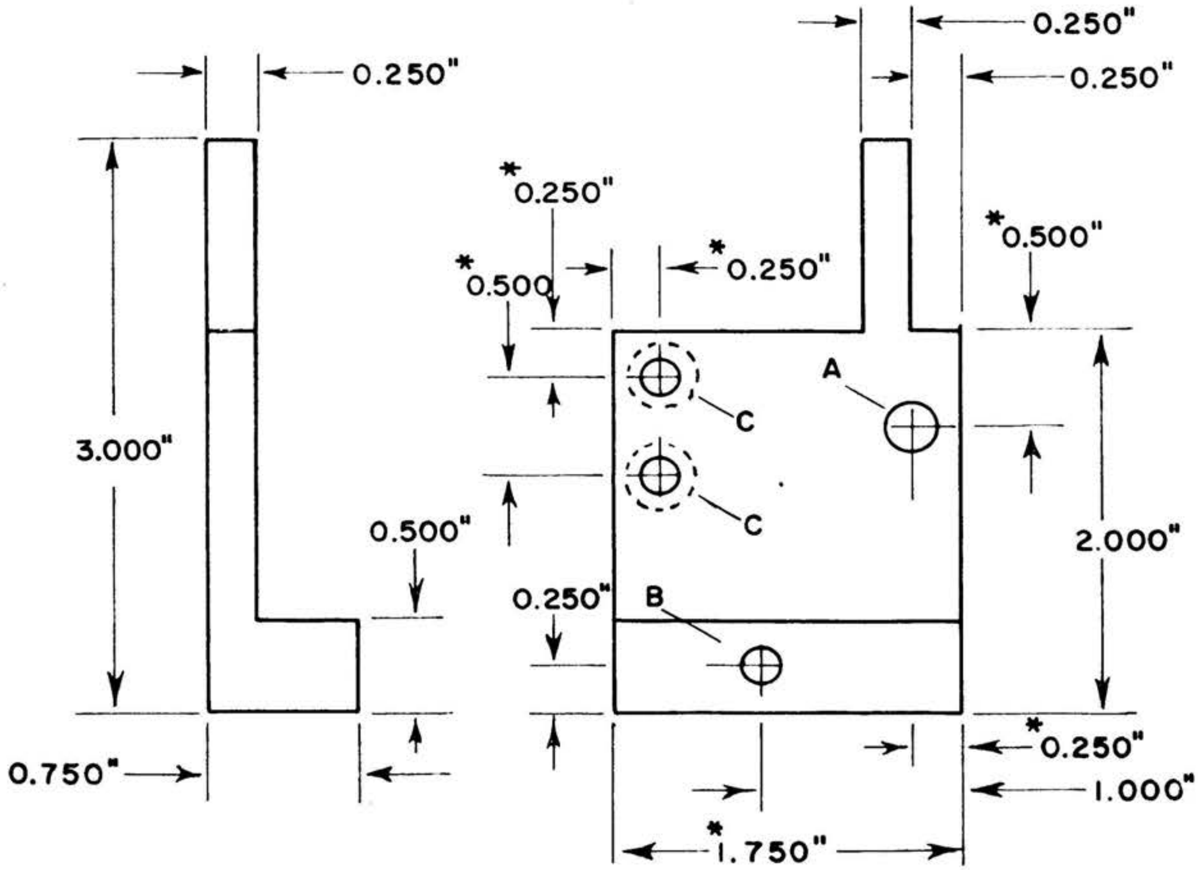


A – 0.250" HOLE.
B – 1/4 – 28 TAP – TIGHT THREAD.
C – No. 11 DRILL – COUNTERSINK ON BACK SIDE.

TOL – ±0.015", (DENOTES 0.005").

MATERIAL – 2024 T4 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	RIGHT HOLDER ARM
	5.02.02

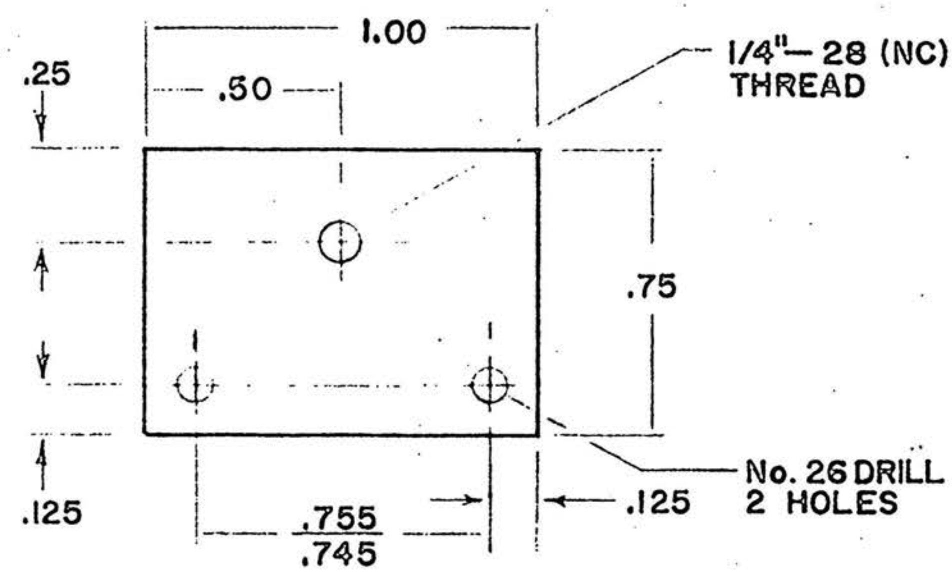


A - 0.250" HOLE
B - 1/4-28 TAP - TIGHT THREAD.
C - No. 11 DRILL - COUNTERSINK ON BACK SIDE.

* TOL - ±0.015" (* DENOTES 0.005").

MATERIAL - 2024 T4 AL.

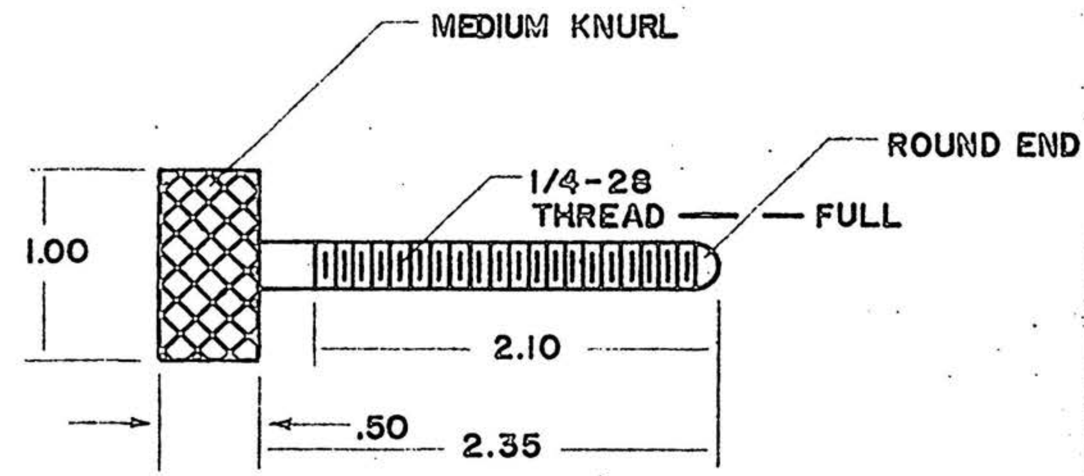
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	LEFT HOLDER ARM
	5.02.03



TOL: ±.015"

.5" BRASS

SCREW HOLDER	5.04.03



TOL: ±.025"

1" BRASS ROD

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

6/16/56	SET SCREW
5.02.04 & 5.04.05	3 REQD.

Drawing 5.03.00-A
Drive Assembly-Base Mounted
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.03.00	5.03.00-A	A	Drive ass'y-Base Mtd.
5.03.01	5.03.01	1	Traveling Ass'y.
5.03.01-A	5.03.01-A		Micrometer Nut
5.03.01-B	5.03.01-B		Drive Bar
5.03.01-C	5.03.01		Pin
5.03.02	5.03.02		Guide Plate
5.03.03-2	5.03.03-2		Guide Bars
5.03.04	5.03.04		Shaft
5.03.05	5.03.05		Screw, Micrometer
5.03.06	5.03.06		Link, Coupling
5.03.07S2	None		Washer, 1/4", 1/16" thick, brass
5.03.08	5.03.08	2	Flange, Coupling
5.03.09S6	None		Screw, Allen, 1/2", 6-32, steel.
5.03.10S1	None		Key, 1-1/2", 1/16" dia., brass rod
5.03.11S4	None		Set screw, 1/8", 6-32, Allen, steel.
5.03.12S3	None		Screw, flat head, brass, 1/2", 8-24.

FABRICATION NOTES:

(1)

Clamp the micrometer nut (5.03.01-A) to the drive bar (5.03.01-B) while soldering so that the centerline of the micrometer screw threaded into the nut will be parallel to the drive bar base and centerline.

(2)

The pin holes in flange 5.03.08 must be drilled to match the holes in flange 5.08.04 of the drive shaft assembly. See drawing 5.08.04.

ASSEMBLY NOTES:

(A)

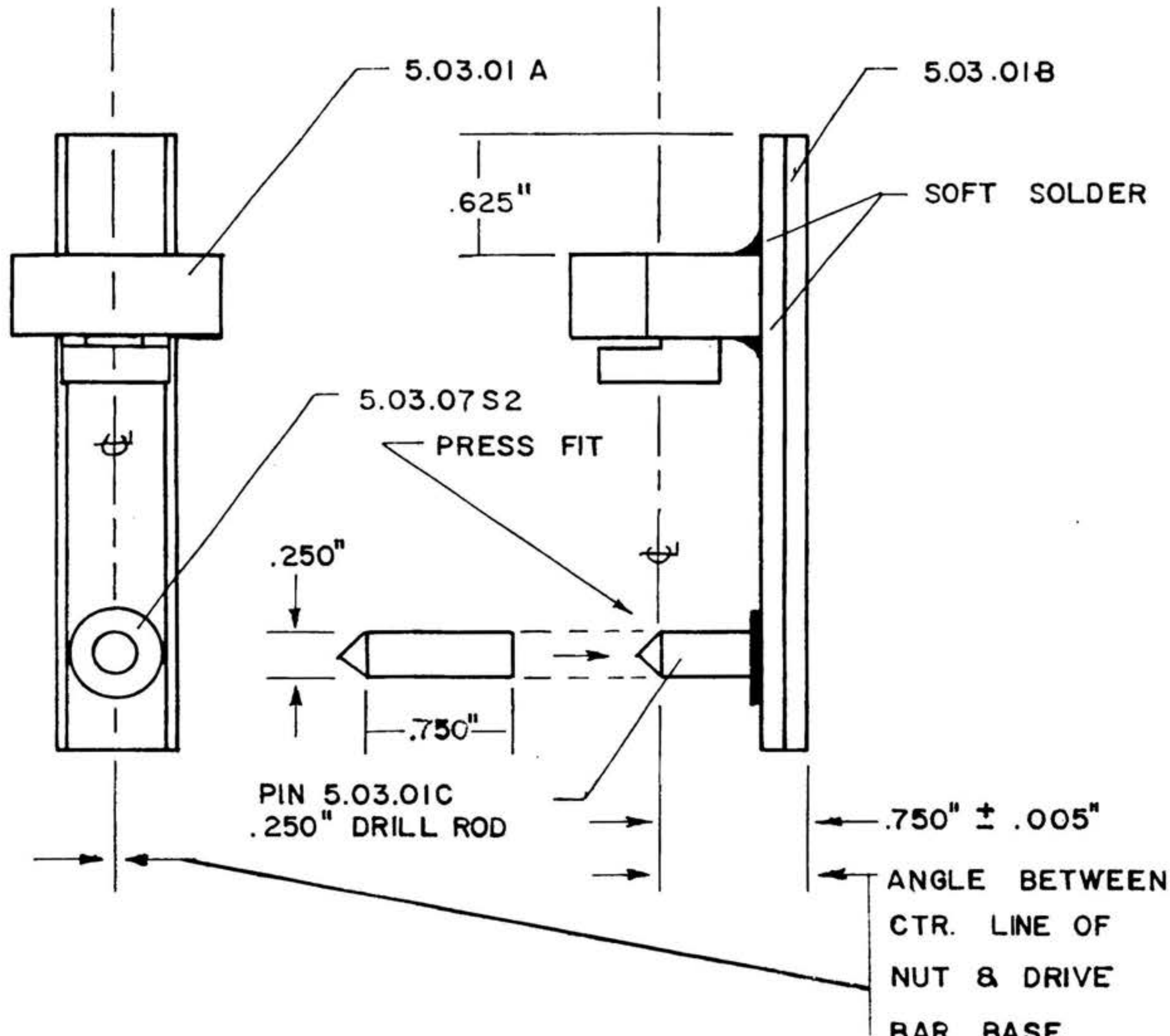
Mount guide plate 5.03.02 on the grating mount base (5.06.01) as indicated in assembly drawings 5.00.00-B & C using three screws (5.03.12S3). Countersink the 5.03.13S2 screw heads and remove any burrs from 5.03.02 that would interfere with the motion of the traveling assembly (5.03.01).

Assemble the micrometer screw (5.03.05) and shaft 5.03.04 so that the centerlines of the two parts coincide. (Wobble of this assembly will cause binding). Lock the micrometer screw into the shaft hole using two set screws (5.03.09S6).

Thread the traveling ass'y (5.03.01) onto the micrometer screw and insert the shaft (5.03.04) through the hole in the shaft guide (5.06.03). Install flange 5.03.08 on the shaft and lock it in place with two 5.03.09S6 set screws so that the shaft assembly turns freely but without end play. (End play can not be tolerated).

Fit the shaft guide to the base plate (5.06.01) so that the traveling ass'y. drive bar slides freely along the guide plate (5.03.02) when the shaft is turned. The shaft guide is attached rigidly to the base plate by two machine screws (5.06.05S2). After alignment of the shaft guide to the base plate is accomplished, drill an 0.250" hole in the guide through the base plate as indicated by drawing 5.06.03 and insert a 5.06.06S3 dowel pin to maintain alignment.

Mount the two traveling assembly guide bars (5.03.03-2) as indicated in dwgs. 5.00.00-B & C. Adjust these bars so that drive bar 5.03.01-B slides between and in contact with the bars without binding. Lock the guide bars in place with the six 5.03.09S6 screws threaded into the guide plate.

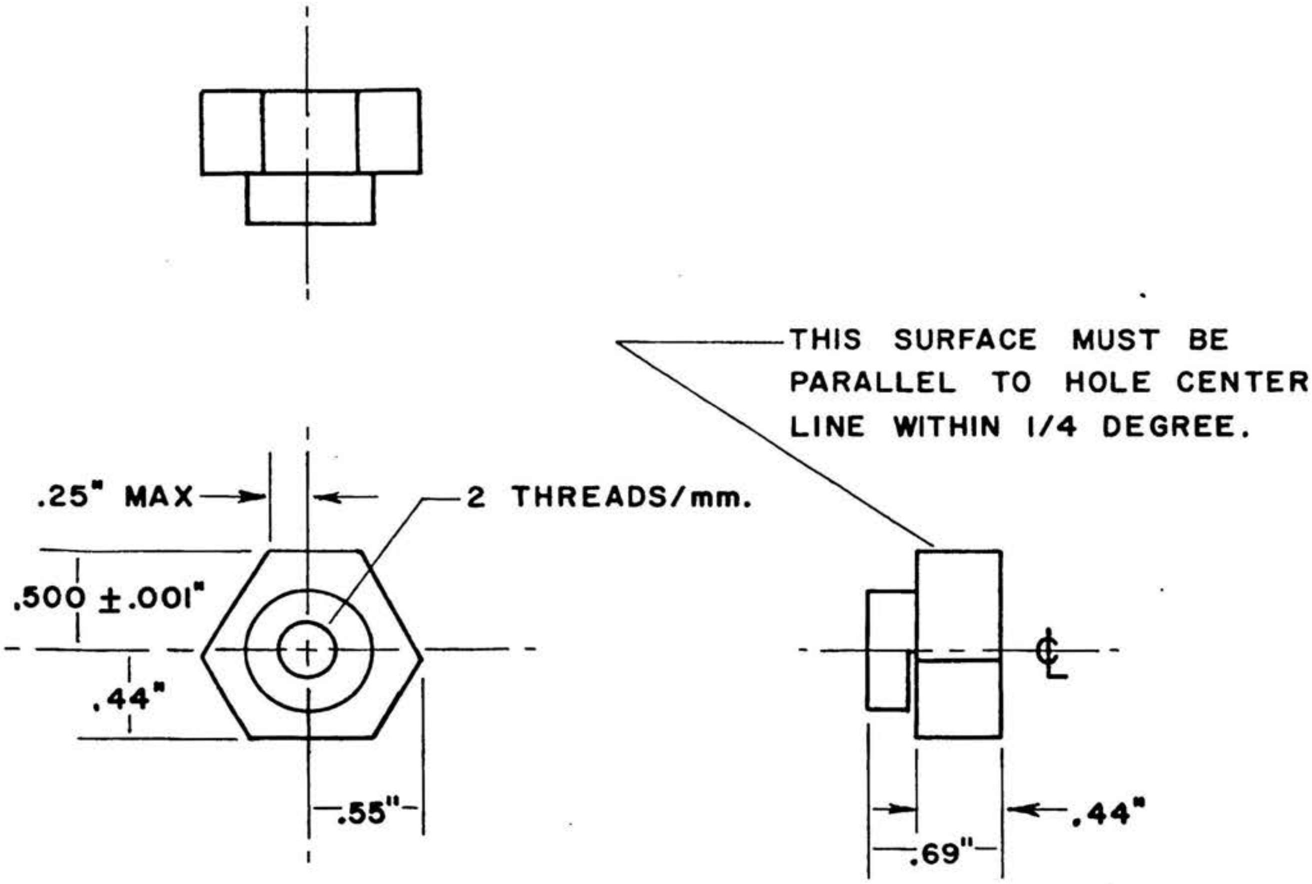


ASSEMBLED VIEW

PARTS: 5.03.01 A, 5.03.01 B, & 5.03.01C.

TOL: ± .015"

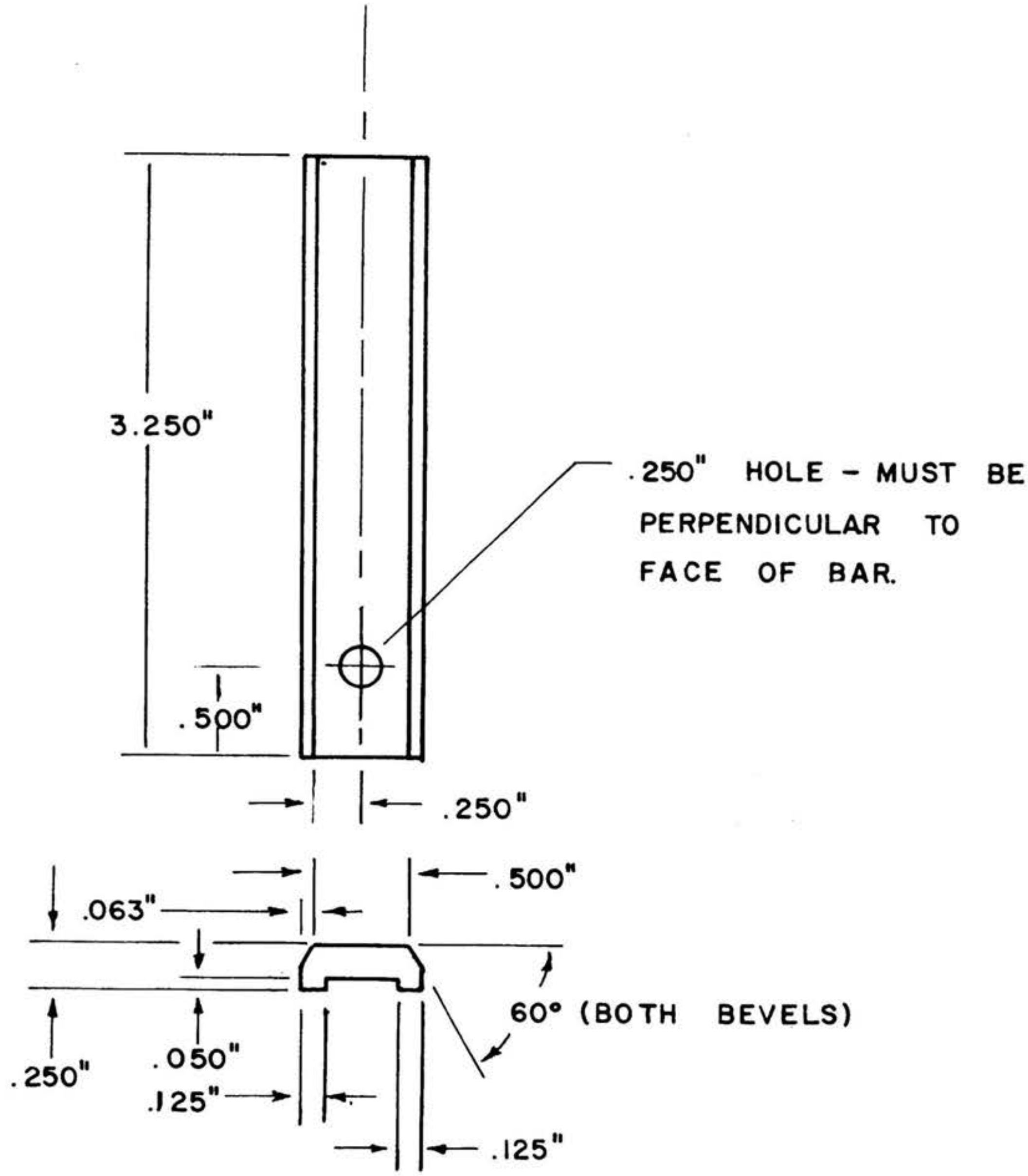
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
D. D. H. 4/21/57	TRAVELING ASSEMBLY
	5.03.01



NOTE: PART IS MADE FROM A "CENCO STUDENT SPHEROMETER" BASE.
ARMS ARE CUT OFF TO LEAVE PART OF INDICATED SHAPE AND SIZE.

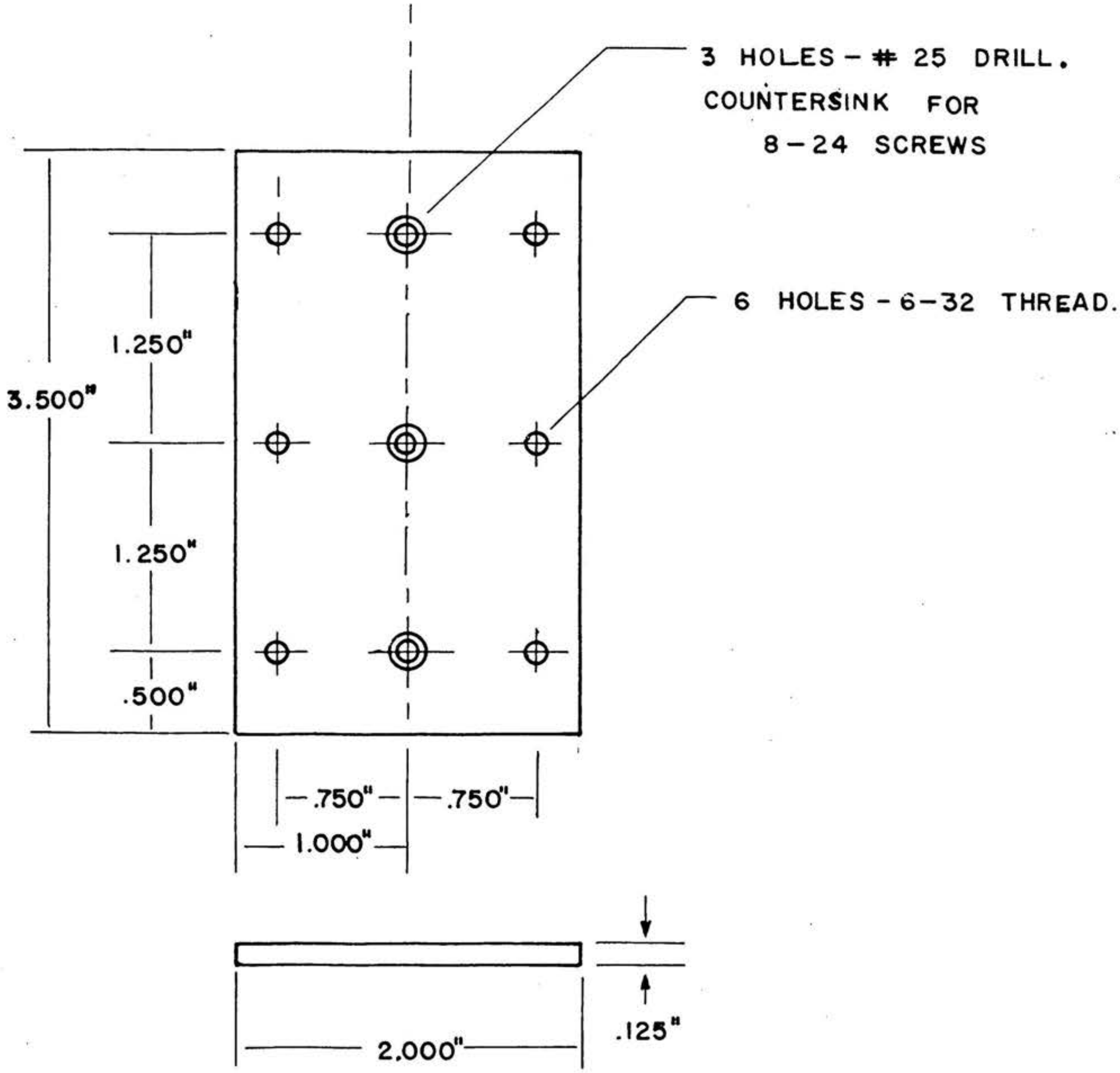
TOL — ± .025" EXCEPT AS NOTED. FULL SCALE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 11/9/58	MICROMETER NUT-GRATING DR.
	5.03.01 A



TOL : ± .015 FULL SCALE MATERIAL - .250" BRASS

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
D.D.H. 4/ 19 /57	DRIVE BAR
	5.03.01 B

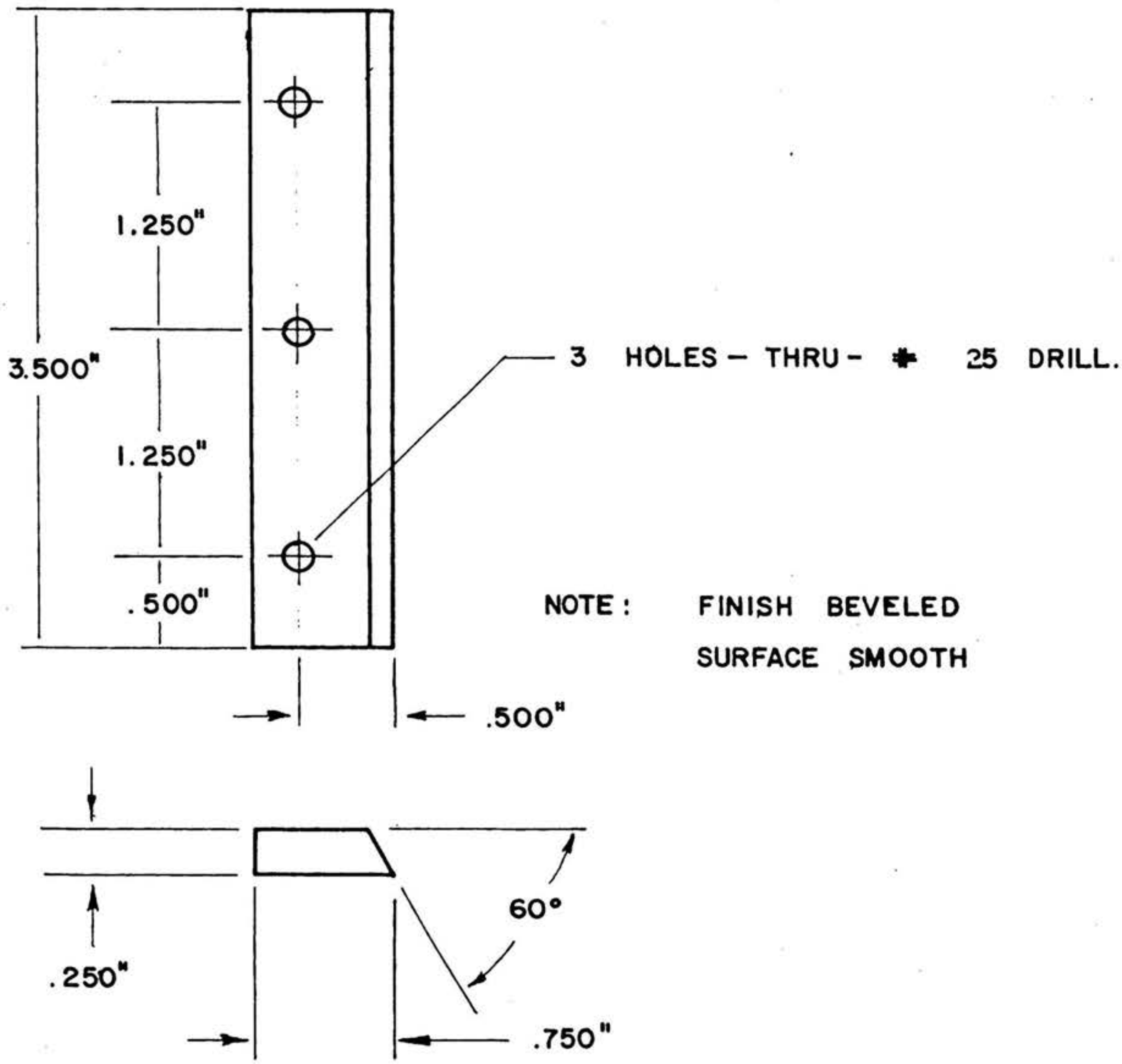


TOL: ± .005" FULL SCALE MATERIAL: .125" BRASS

M.S.M. PHYSICS DEPT.

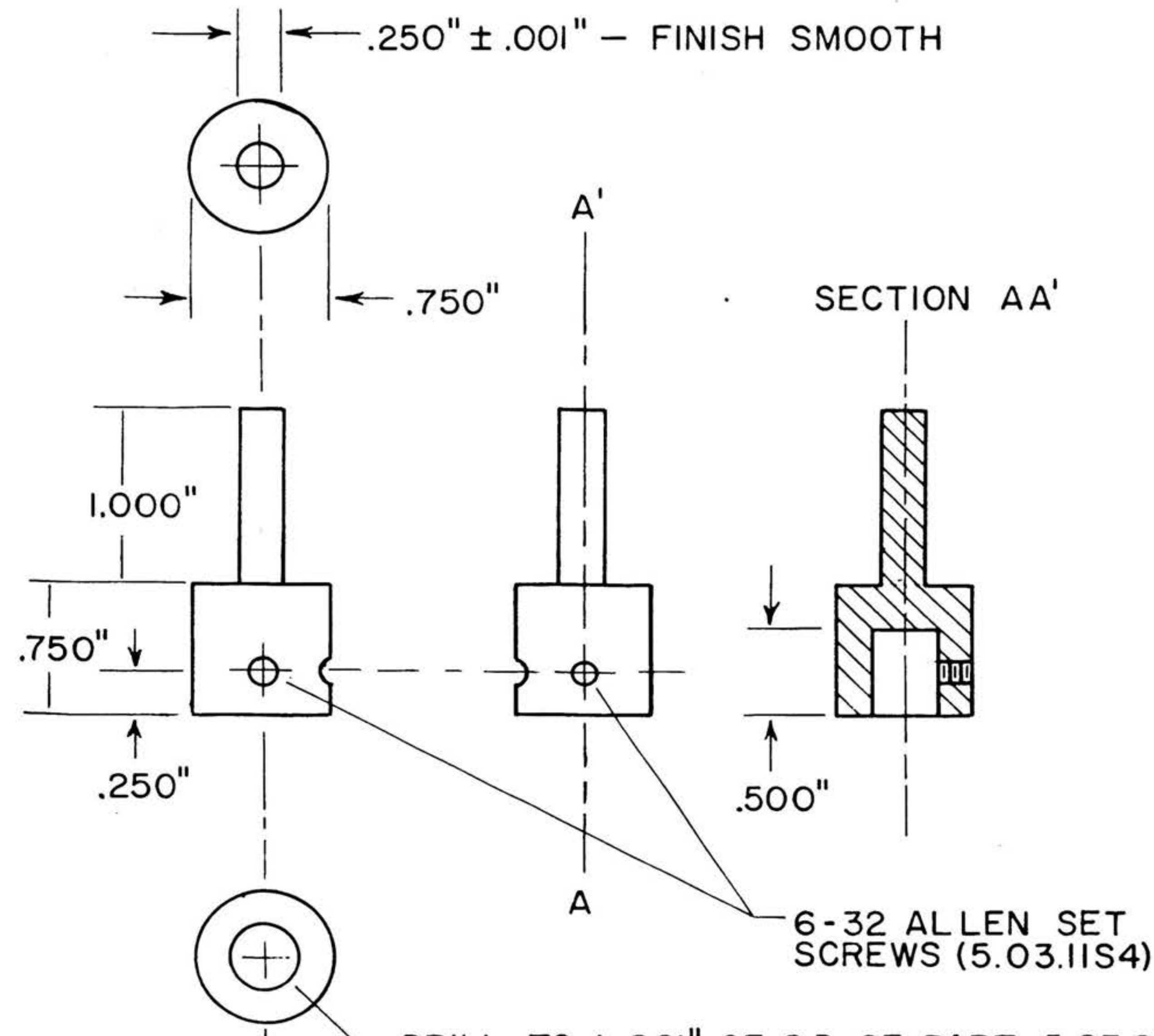
VACUUM SPECTROGRAPH

D.D.H. 4 / 19 / 57	PLATE, GUIDE
	PART. 5.03.02



TOL; ± .005" FULL SCALE MATERIAL: .250" BRASS

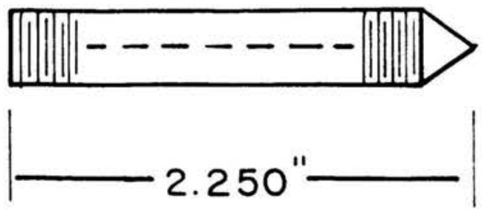
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
D.D.H. 4/ 20 / 57	GUIDE BARS
	5. 03.03-2



DRILL TO ±.001" OF O.D. OF PART 5.03.05.
THIS HOLE MUST BE CONCENTRIC WITH
THE .250" SHAFT ON OPPOSITE SIDE
WITHIN .001". ANGLE BETWEEN THE
CENTER LINES SHOULD BE LESS
THAN 1/4 DEGREE.

FULL SCALE
TOL: ± .015"
MATERIAL: .750" BRASS ROD

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
J.K.H. 5/27/57	SHAFT
	5.03.04



NOTE: MODIFY A "CENCO STUDENT SPHEROMETER" .5 MM. PITCH MICROMETER SCREW BY SHORTENING TO THE INDICATED LENGTH.

MATERIAL:
"CENCO STUDENT SPHEROMETER SCREW"

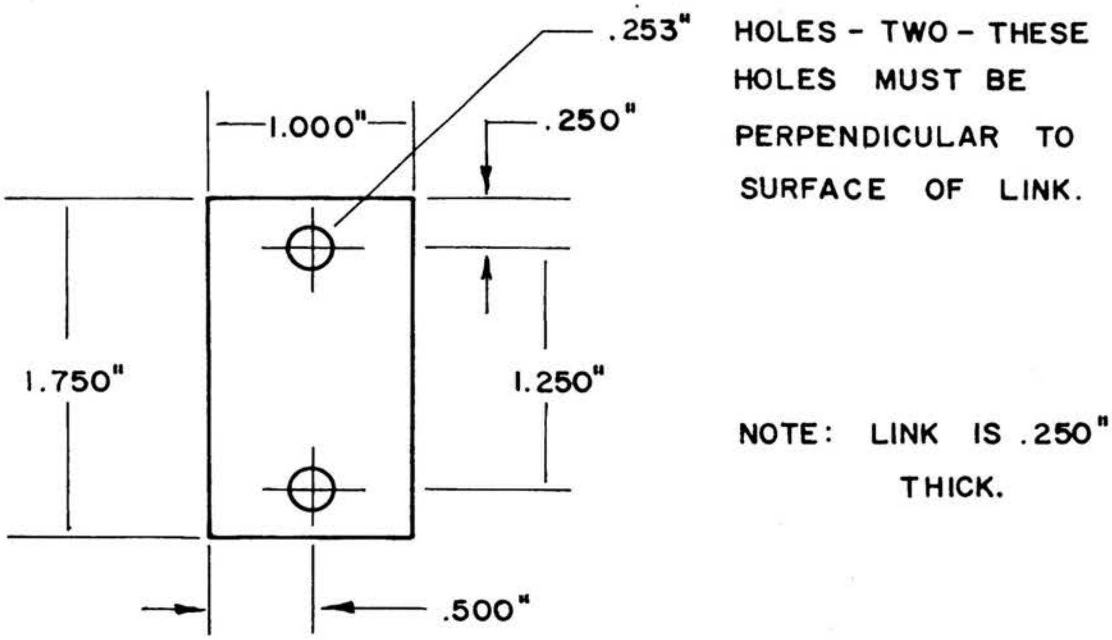
NOT TO SCALE:

TOL: ± .05"

M.S.M. PHYSICS DEPT.

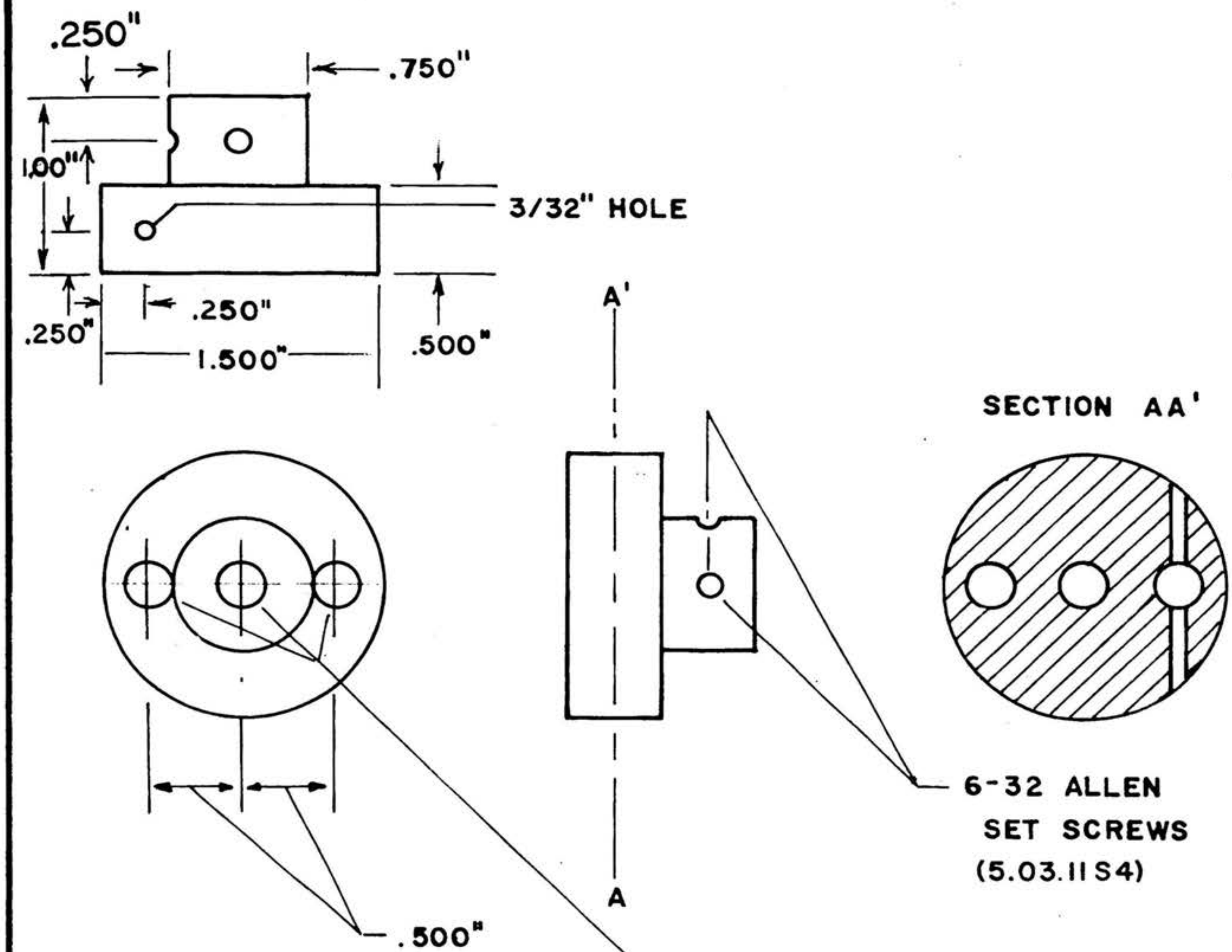
VACUUM SPECTROGRAPH

D.D.H. 4/18/57	SCREW, MICROMETER
	5.03.05



TOL : .015" FULL SCALE MATERIAL : .250" BRASS PLATE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
D.D.H. 4 / 21 / 57	LINK, COUPLING
	5.03.06



.253" HOLES - THREE.
SEE NOTE ON DWG. 5.08.04.
DRILL AT .250" & REAM TO .253."
CENTER HOLE IS REAMED TO
.253" ONLY TO DEPTH OF .500"
FROM FLANGE FACE.

TOL : ± .015" FULL SCALE MATERIAL: 1.500" BRASS ROD

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
D.D.H. 4 / 18 / 57	FLANGE, COUPLING
	5.03.08

Drawing 5.04.00-A
Upright Assembly
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No.	Note:	Description:
5.04.00	5.04.00-A	A	Upright Assembly
5.04.01	5.04.01		Upright
5.04.02	5.04.02		Upright
5.04.03	5.02.04 5.04.03 5.04.05		Adjustment Screw Holder
5.04.04	5.04.04		Upper Base Plate
5.04.05	5.02.04 5.04.05 5.04.03		Adjustment Screw
5.04.06	5.04.06		Pressure Rod
5.04.07S1	None		Spring, compression, 1/2", 3/16" dia., 1# force/ 0.25".
5.04.08	None		P/N not used
5.04.09S2	None		Screw, 2", 6-32, round head, brass.
5.04.10S4	None		Screw, 3/4", 6-32, flat head, brass.
5.04.11	5.04.11		Pressure Rod Holder
5.04.12S2	None		Hex Nut, 6-32, brass

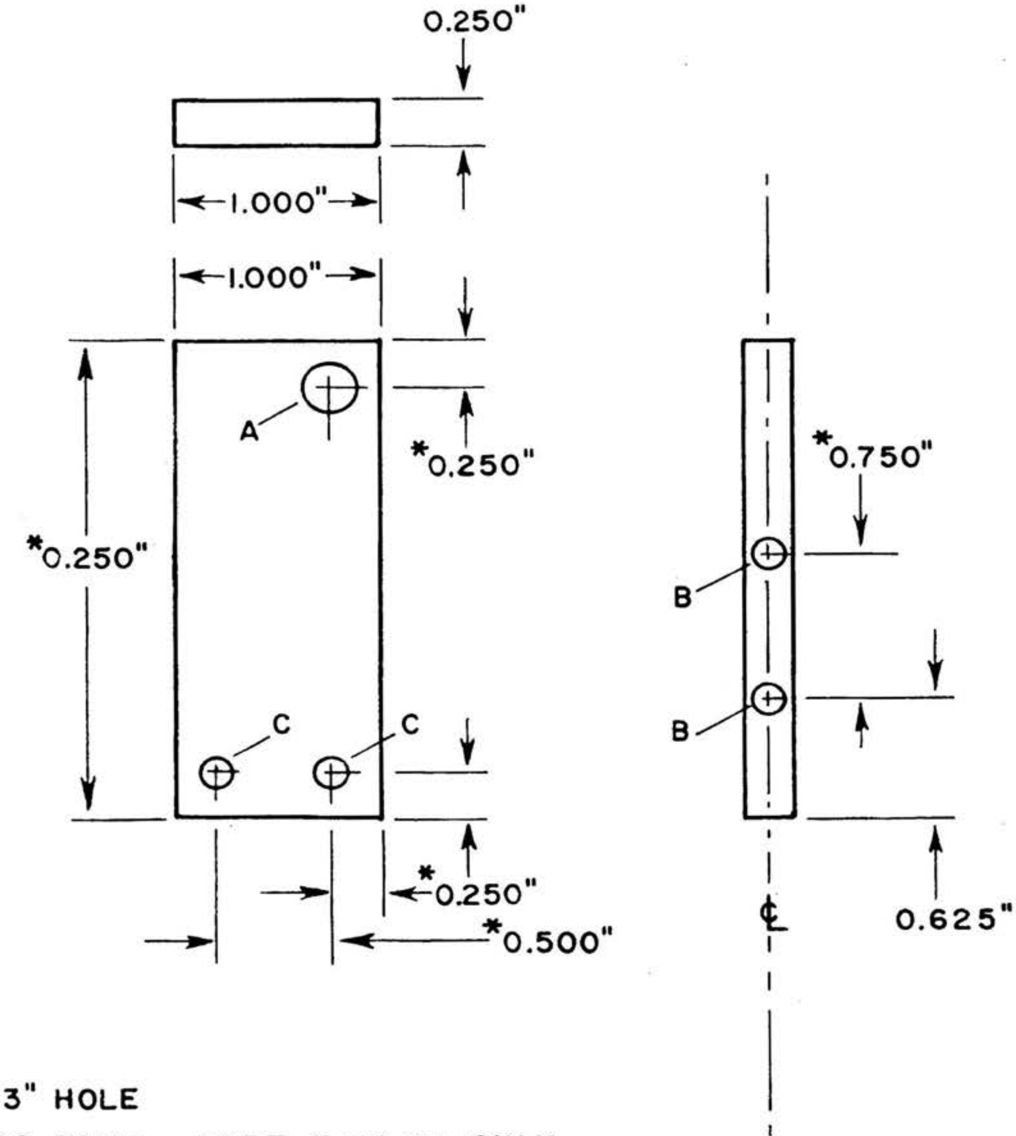
ASSEMBLY NOTES:

(A)

Place centering washers 5.02.07S2 on shafts 5.02.09S2 as indicated in drawing 5.00.00-C.. Slip the uprights (5.04.01 & 5.04.02) onto shafts 5.02.09S2 and attach them rigidly to the upper base plate (5.04.04) as indicated by dwgs. 5.00.00-E & F with four 5.04.10S4 screws.

Caution: The uprights must be aligned so that the bracket assembly shafts turn without binding.

Insert spring 5.04.07S1 and pressure rod 5.04.06 into the 1/4" hole in the pressure rod holder (5.04.11). Mount the rod holder and adjustment screw holder on upright 5.04.02 so that the pressure rod pushes against the arm extending downward from part 5.02.03. Thread adjustment screw 5.04.05 into its holder.



A – 0.253" HOLE

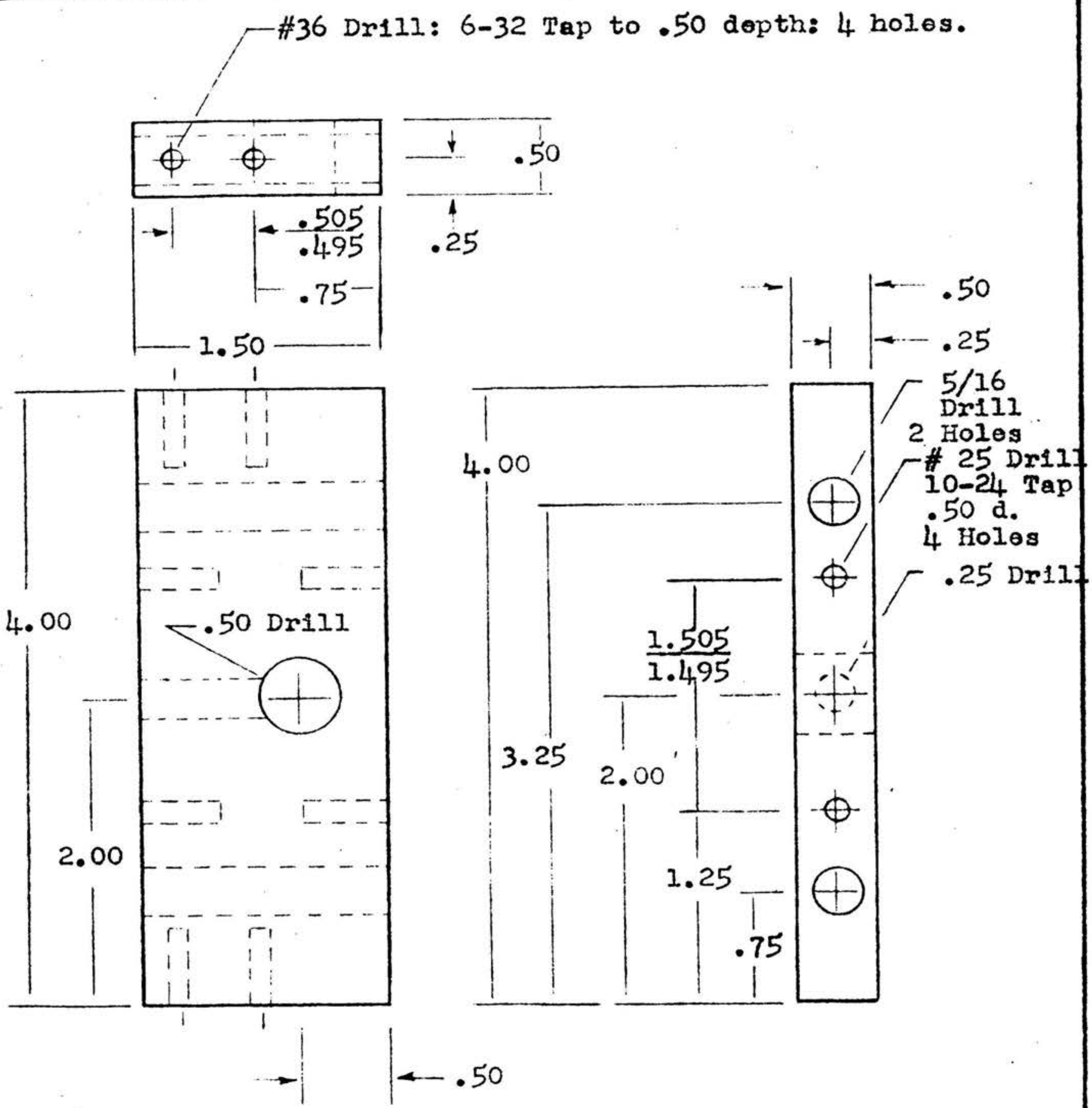
B – No. 26 DRILL. – PART 5.04.02 ONLY.

C – No. 26 DRILL. – COUNTERSINK – TOP SIDE OF 5.04.02.
– BOTTOM SIDE OF 5.04.01.

* TOL – ±0.015" (* DENOTES 0.005".)

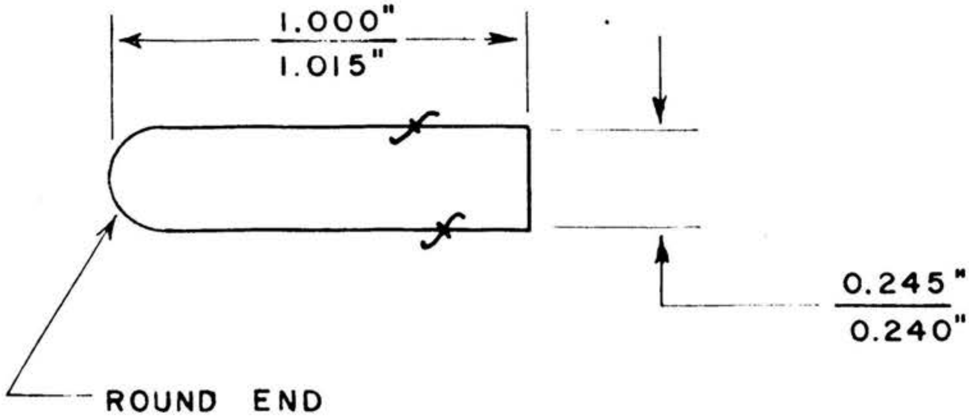
MATERIAL – 2024 T4 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
UPRIGHT – RIGHT	UPRIGHT – LEFT
5.04.01	5.04.02



Tol: ∠ .02 Except as indicated.
Material: .500 Aluminum plate.
Scale: Full

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
5/2/56	BASE PLATE – UPPER
J.K.H.	5.04.04



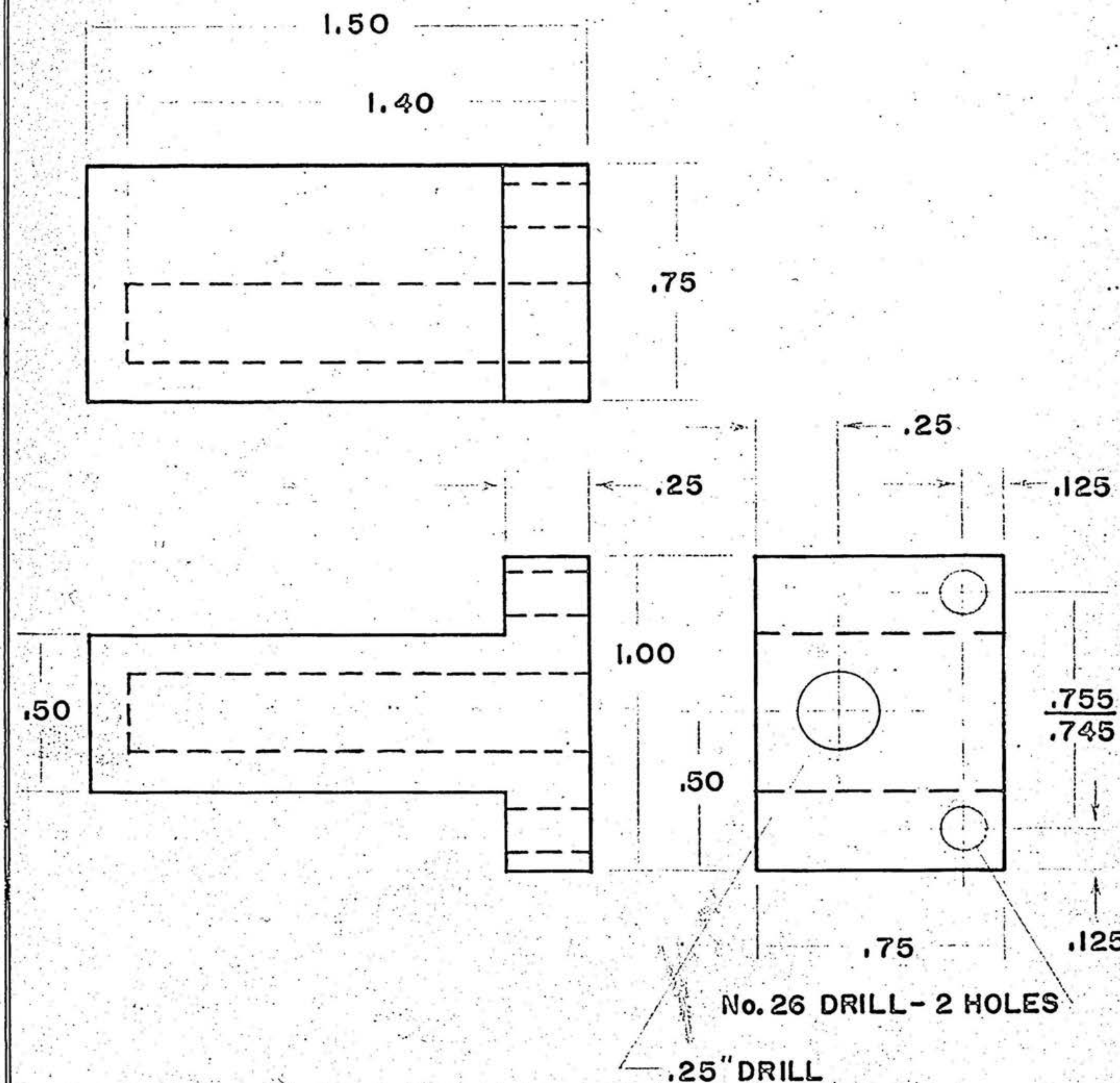
FINISH SIDE SURFACE TO 0.000 5" ROUGHNESS OR BETTER.

MATERIAL – YELLOW BRASS

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

	PRESSURE ROD
	5.04.06



TOL: ± .02"

MATERIAL — AL. OR BRASS

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 6/19/56	PRESSURE ROD HOLDER
	PART No. 5.04.11

Drawing 5.05.00-A
Lower Base Assembly
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.05.00	5.05.00-A	A	Lower Base Ass'y.
5.05.01	5.05.01	1	Guide Rod Holder-Rear
5.05.02S2	None		Guide Rod, 4.50", 0.250" dia. polished steel drill rod.
5.05.03	5.05.03		Collar
5.05.04	5.05.04		Adjustment Screw
5.05.05	5.05.05	2	Flange, Bearing
5.05.06	5.05.06		Base Plate-lower
5.05.07	5.05.07	2	Grating Drive Arm Plate
5.05.08S1	None	3	Bearing, Roller, 1.000" I.D., 1/16" height, 2-1/32" O.D., New Departure #3205.
5.05.09	5.05.09	1	Guide Plate-Rear
5.05.10	5.05.10	1	Guide Plate-Front
5.05.11	5.05.11	1	Guide Rod Holder-Front
5.05.12S4	None		Screw, round head, 1", 10-24, brass.
5.05.13S8	None		Screw, round head, 1", 6-32, brass.
5.05.14S8	None		Hex Nut, 6-32 brass
5.05.15S7	None		Set Screw, Allen, 1/8", 6-32, steel
5.05.16-2	5.05.07	4	Pin

FABRICATION NOTES:

(1)

The 1/4" holes for the guide rods (5.05.02S2) in parts 5.05.01, 5.05.09, 5.05.10 & 5.05.11 must be drilled with these parts clamped together in order to obtain equal spacing. See notes on dwgs.

(2)

Soft solder bearing flange 5.05.05 and pins 5.05.16-2 to the drive arm plate as indicated by drawing 5.05.07. Avoid application of excessive heat when soldering the flange in place to minimize wraping of the plate.

(3)

Remove all oil and grease from bearing before use.

ASSEMBLY NOTES:

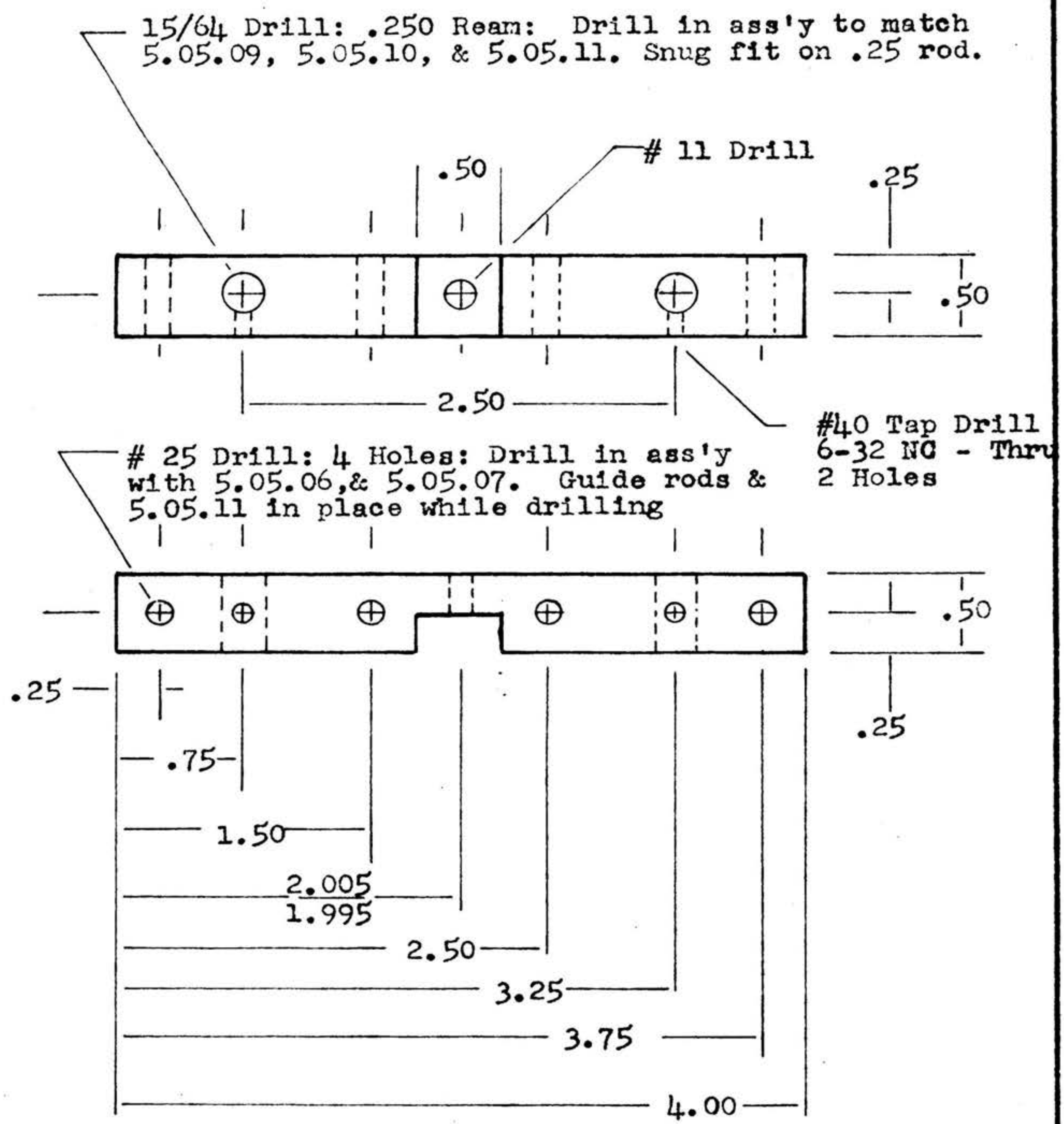
(A)

Insert 0.250" polished steel rods through the two holes in guide plates 5.05.09 & 5.05.10 when mounting them to the upper base plate (5.04.04). Adjust the guides so that the rods move freely after the 5.05.12S4 screws are tightened. The guide plates must be adjusted so that the upper base (5.04.04) does not extend below the bottom sides of the guide plates.

Insert the guide rods (5.05.02S2) through the guide plates attached to the upper base and through rod holders 5.05.01 & 5.05.11 and clamp the rod holders in place to the lower base plate (5.05.06) and the drive arm plate (5.05.07) while the mounting holes are being drilled. See drawings 5.05.06 & 5.05.07. Insert screws 5.05.13S8 and tighten nuts 5.05.06 & 5.05.07. Insert screws 5.05.13S8 and tighten nuts 5.05.14S8 before removing clamps.

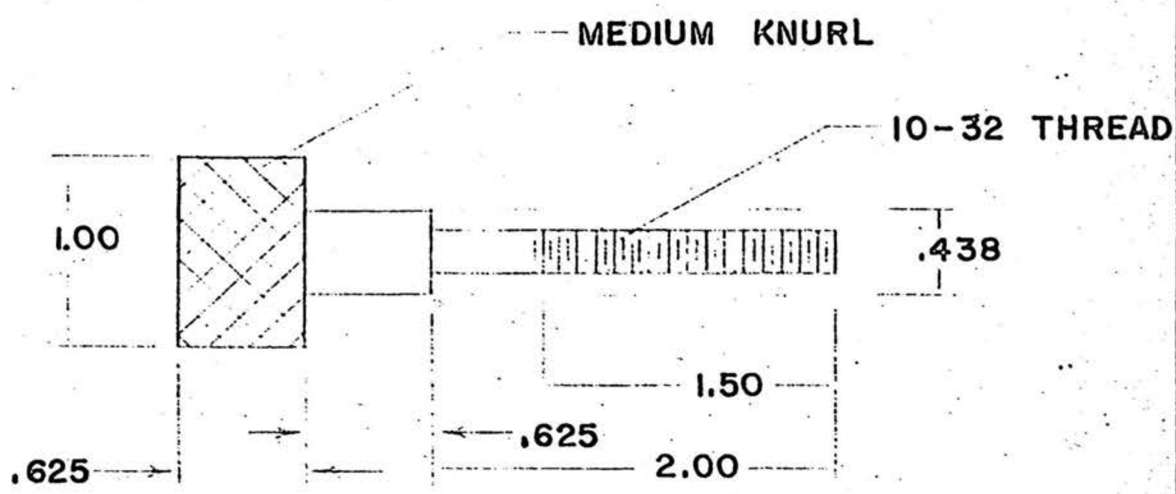
Caution: Adjust the rod holders before drilling so that the upright assembly (5.04.00) moves freely along the guide rods.

Install adjustment screw 5.05.04 and lock collar 5.05.03 in place with a 5.05.15S7 set screw so that it turns without end play.



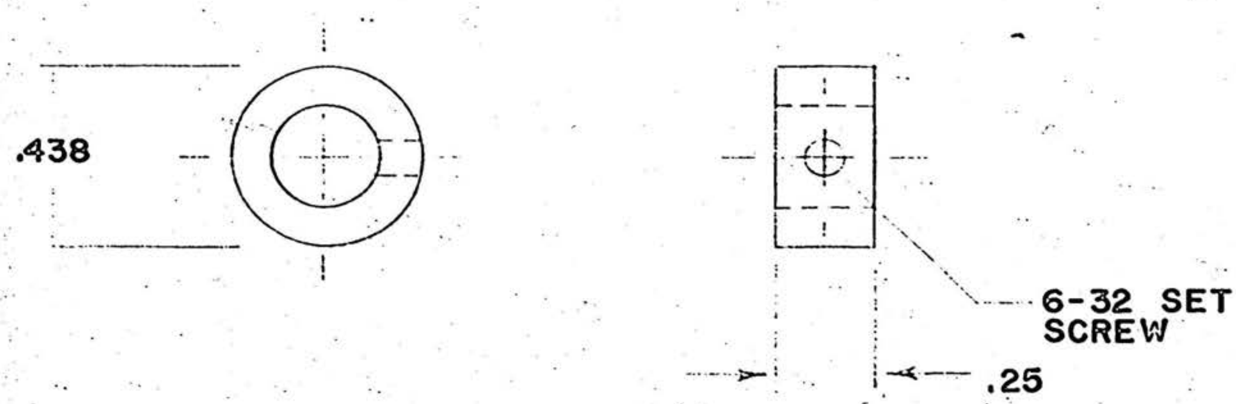
Tol: ± .02 Except as noted
Material: Bronze or Brass square stock.
Scale: Full

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
5/2/56	GUIDE ROD HOLDER
J.K.H.	5.05.01



1" BRASS ROD

HORZ. ADJ. SCREW 5.05.04

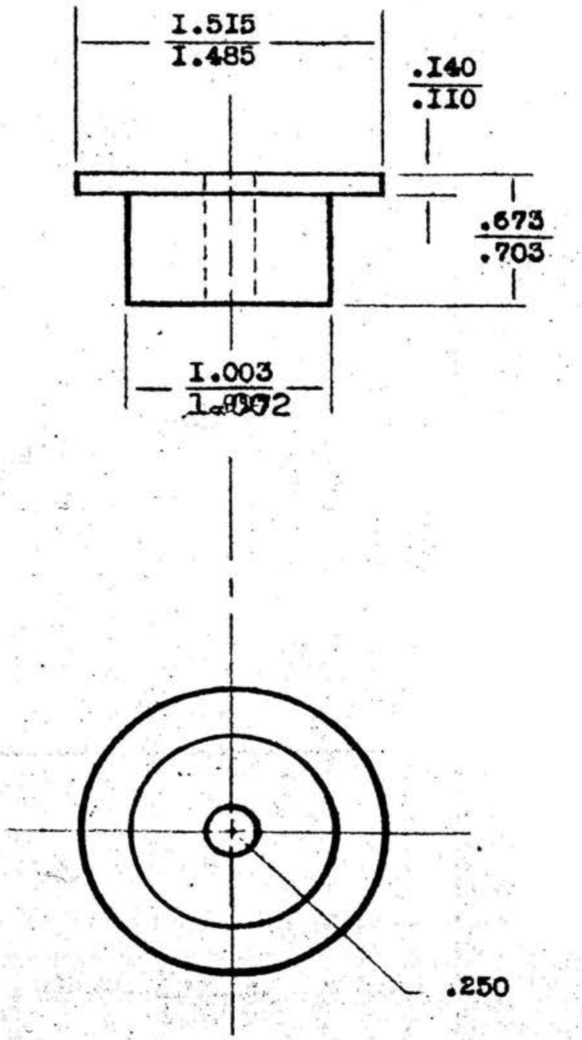


.5" BRASS ROD

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

6/16/56	COLLAR
JKH	5.05.03



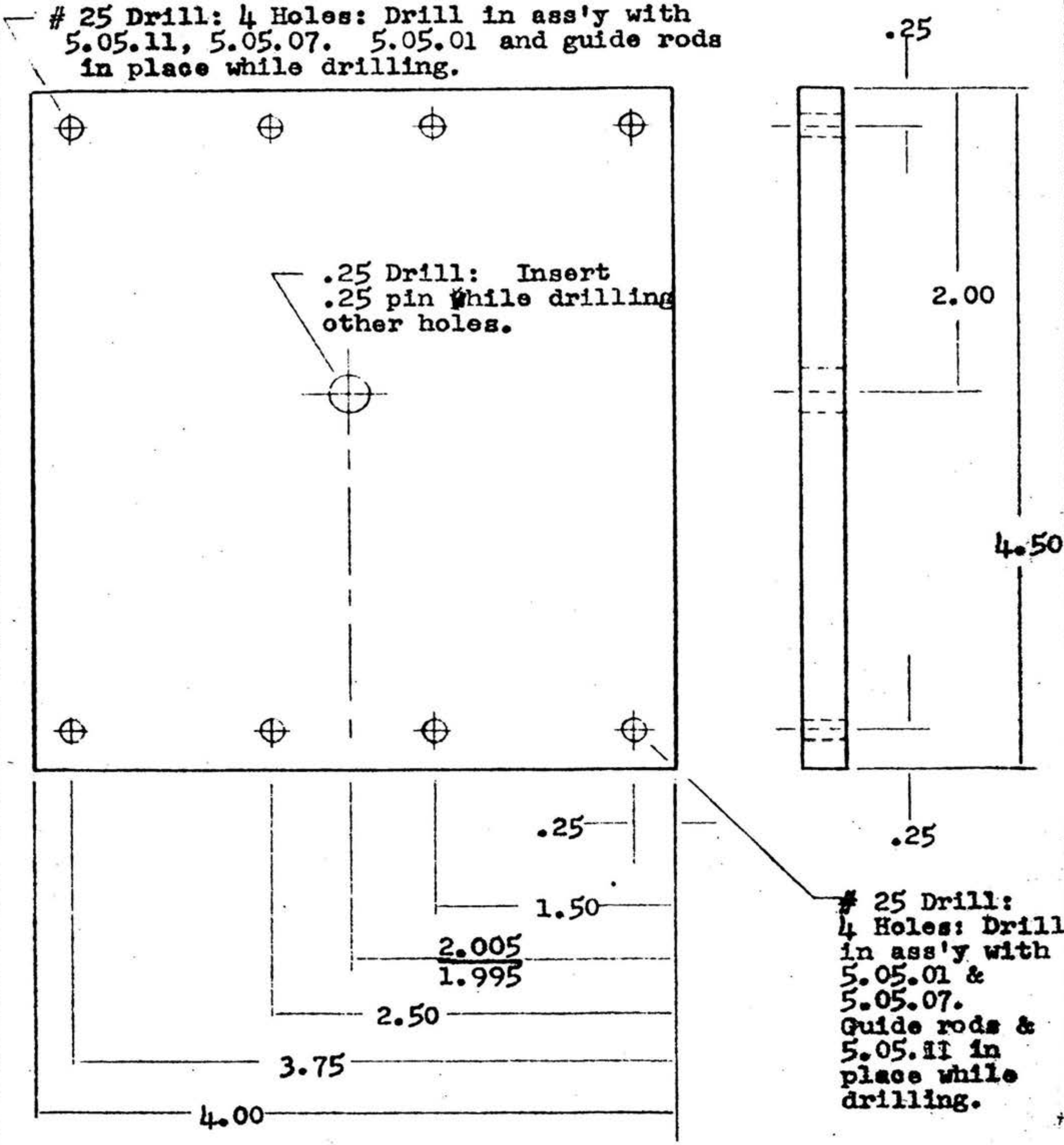
Note: This Flange
is soldered to
Part #5-05-07
Per Ass'y. Dwg.
5-05-07

Full Scale:
Material: I$\frac{1}{2}$" Brass Rod

M.S.M. PHYSICS DEPARTMENT

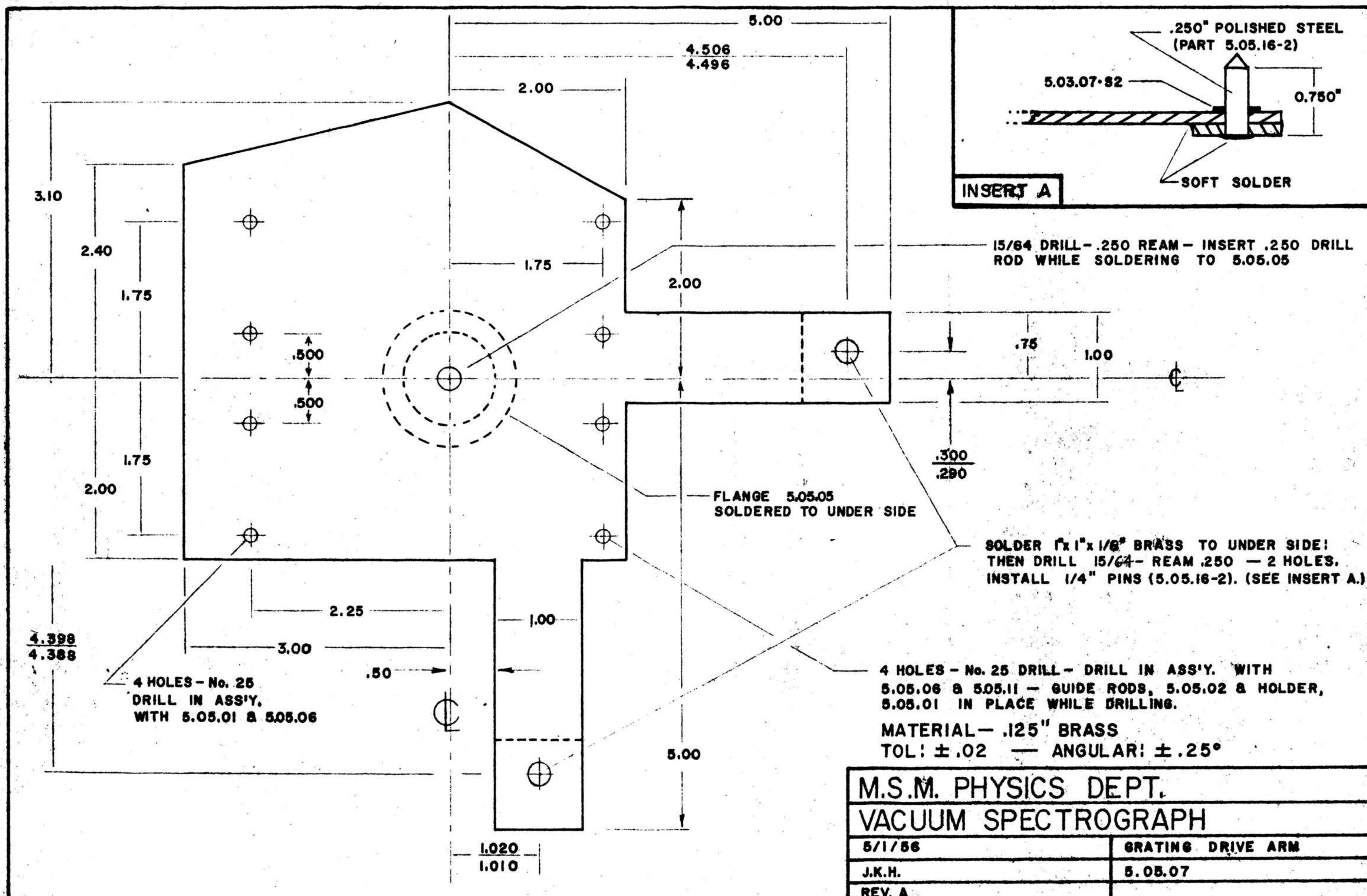
VACUUM SPECTROGRAPH

FEBRUARY 20, 1956	FLANGE
DRAWN BY: BRAUN	NO. 5-05-05
CHECKED BY:	DRAWING NO. 5-05-05

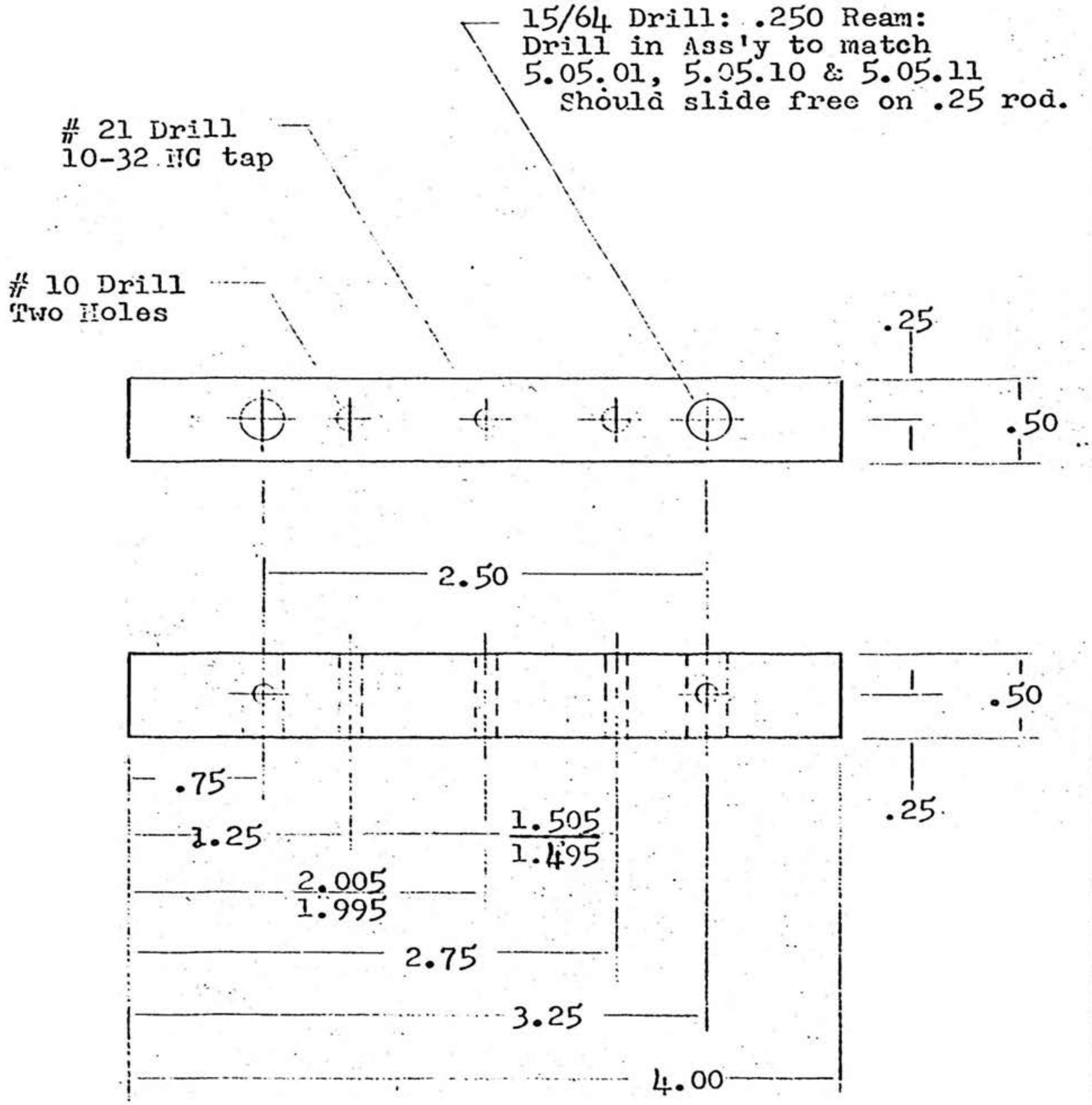


Tol: ∠ .02 Except as indicated
Material: .250 High Brass Plate
Scale: Full

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
5/2/56	BASE PLATE - LOWER
J.K.H.	5.05.06

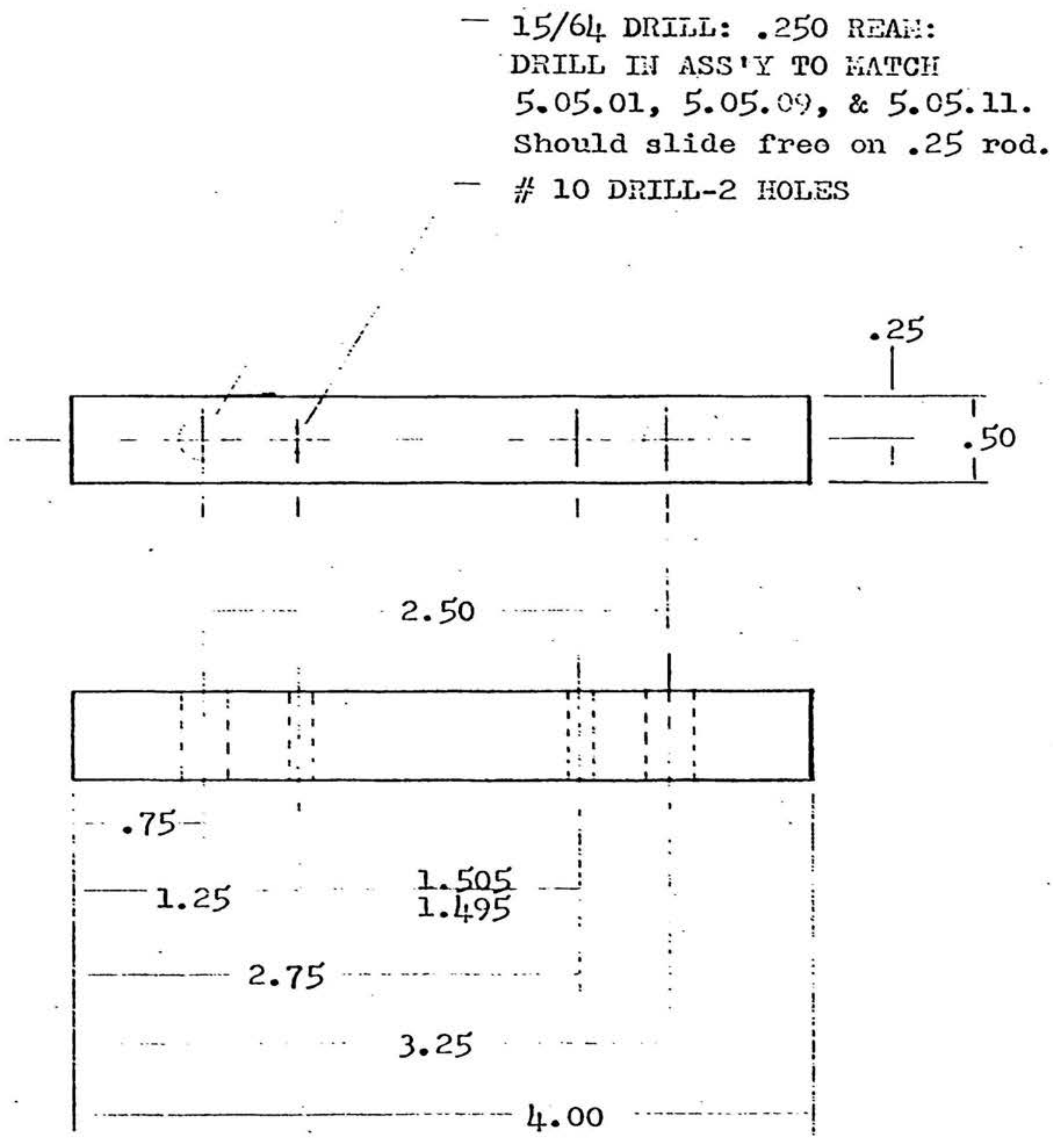


5.00
4.506
4.496
2.00
.250" POLISHED STEEL
(PART 5.05.16-2)
5.03.07-S2
0.750"
SOFT SOLDER
INSERT A
3.10
2.40
1.75
2.00
15/64 DRILL - .250 REAM - INSERT .250 DRILL ROD WHILE SOLDERING TO 5.05.05
.500
.500
.75
1.00
.300
.290
1.75
2.00
FLANGE 5.05.05 SOLDERED TO UNDER SIDE
SOLDER 1"x 1"x 1/8" BRASS TO UNDER SIDE! THEN DRILL 15/64 - REAM .250 — 2 HOLES. INSTALL 1/4" PINS (5.05.16-2). (SEE INSERT A.)
2.25
1.00
3.00
4.398
4.388
.50
4 HOLES - No. 25 DRILL IN ASS'Y. WITH 5.05.01 & 5.05.06
4 HOLES - No. 25 DRILL - DRILL IN ASS'Y. WITH 5.05.06 & 5.05.11 - GUIDE RODS, 5.05.02 & HOLDER, 5.05.01 IN PLACE WHILE DRILLING.
MATERIAL — .125" BRASS
TOL: ± .02 — ANGULAR: ± .25°
5.00
1.020
1.010
M.S.M. PHYSICS DEPT.
VACUUM SPECTROGRAPH
5/1/56
GRATING DRIVE ARM
J.K.H.
5.05.07
REV. A



Tol: ∠ .02 Except as noted.
Material: .50" Bronze or Brass Square Stock
Scale: Full

Missouri School of Mines Physics Dept.	
Vacuum Spectrograph	
5/2/56	Guide Plate - Rear
Drawn by J.K.H.	
	Part # 5.05.09

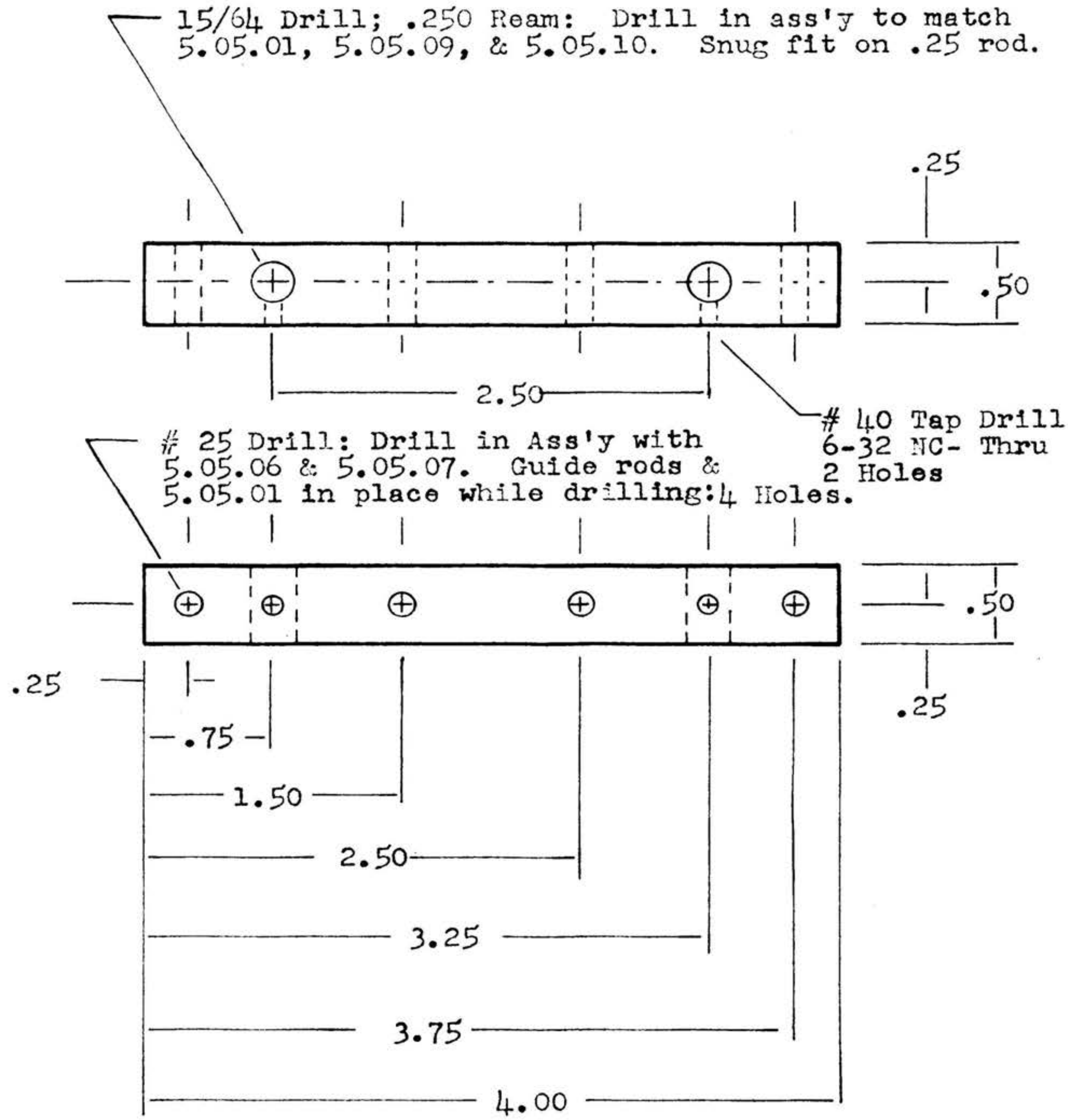


Tol: ∠ .02 except as noted.
Material: .50" Brass or Bronze Square Stock
Scale: Full

Missouri School of Mines Physics Dept.

Vacuum Spectrograph

5/2/56	Guide Plate - Front
Drawn by J.K.H.	Part # 5.05.10



Tol: ≤ .02 Except as noted.
Material: Bronze or Brass square stock.
Scale: Full

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
5/2/56	GUIDE ROD HOLDER
J.K.H.	5.05.11

Drawing 5.06.00-A
Grating Mount Base Assembly
Vacuum Spectrograph
M.S.M. Physics Dept.

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.06.00	5.06.00-A	A	Grating Mount Base Ass'y.
5.06.01	5.06.01	1	Base Plate
5.06.02	5.01.02 5.06.02		Marker
5.06.03	5.06.03	2	Shaft Guide
5.06.04S2	None		Screw, Allen, 3/4", 6-32, brass.
5.06.05S2	None		Screw, Allen, 1", 8-32, brass.
5.06.06S3	None		Pin, 1", 0.250" dia., steel.
5.06.07S4	None		Screw, Allen, 1", 10-24, brass.

FABRICATION NOTES:

(1)

The 0.250" hole at the center of the 2.046" counterbore must be concentric with the counterbore to within 0.001".

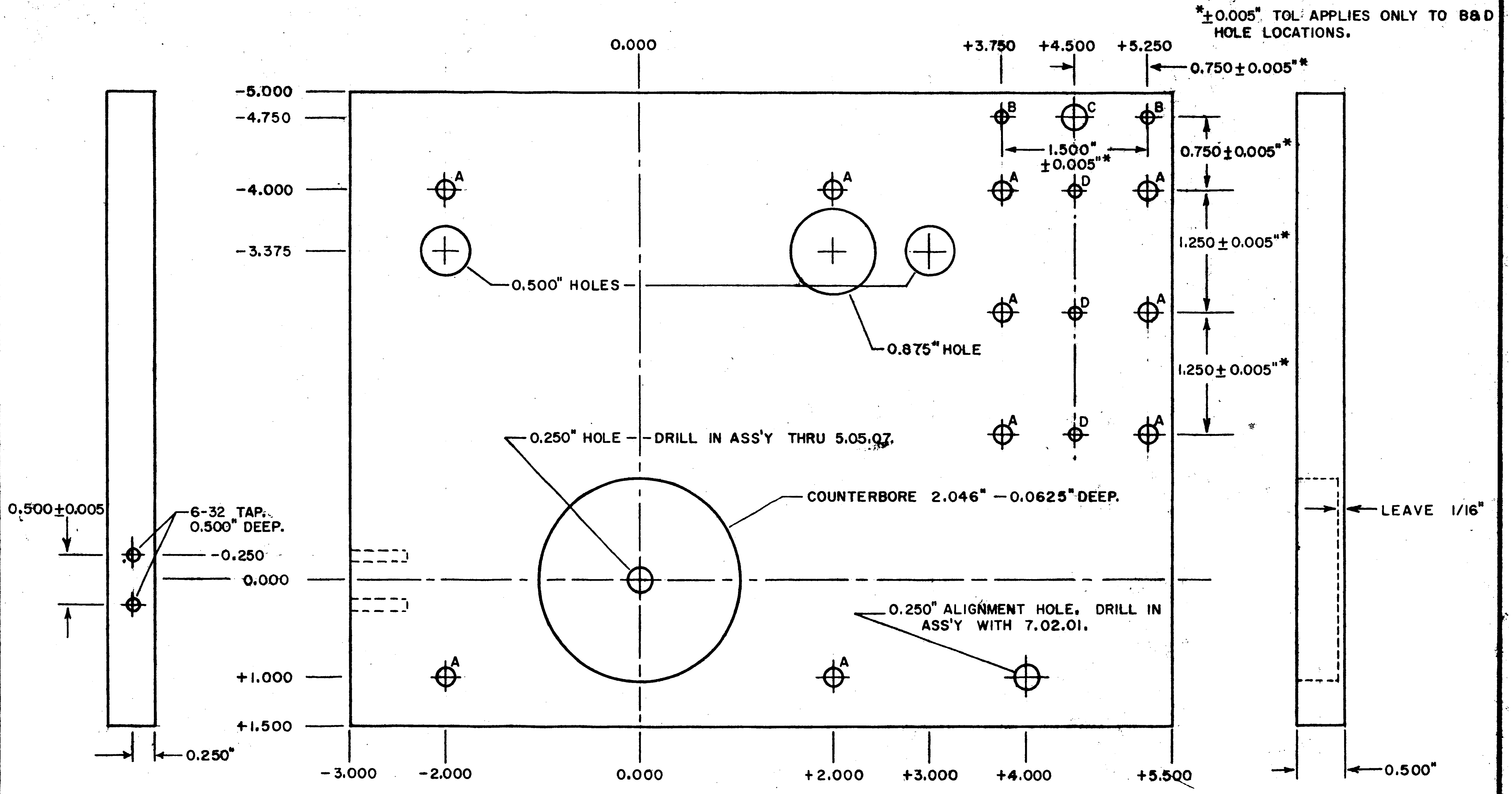
(2)

Fit shaft guide 5.06.03 to the base plate in accordance with assembly note A, dwg. 5.03.00-A. Finish both faces smooth as indicated in dwg. 5.06.03.

ASSEMBLY NOTES:

(A)

Mount marker 5.06.02 and install bearing 5.05.08S1. Read assembly note A, dwg. 5.03.00-A before mounting shaft guide 5.06.03.



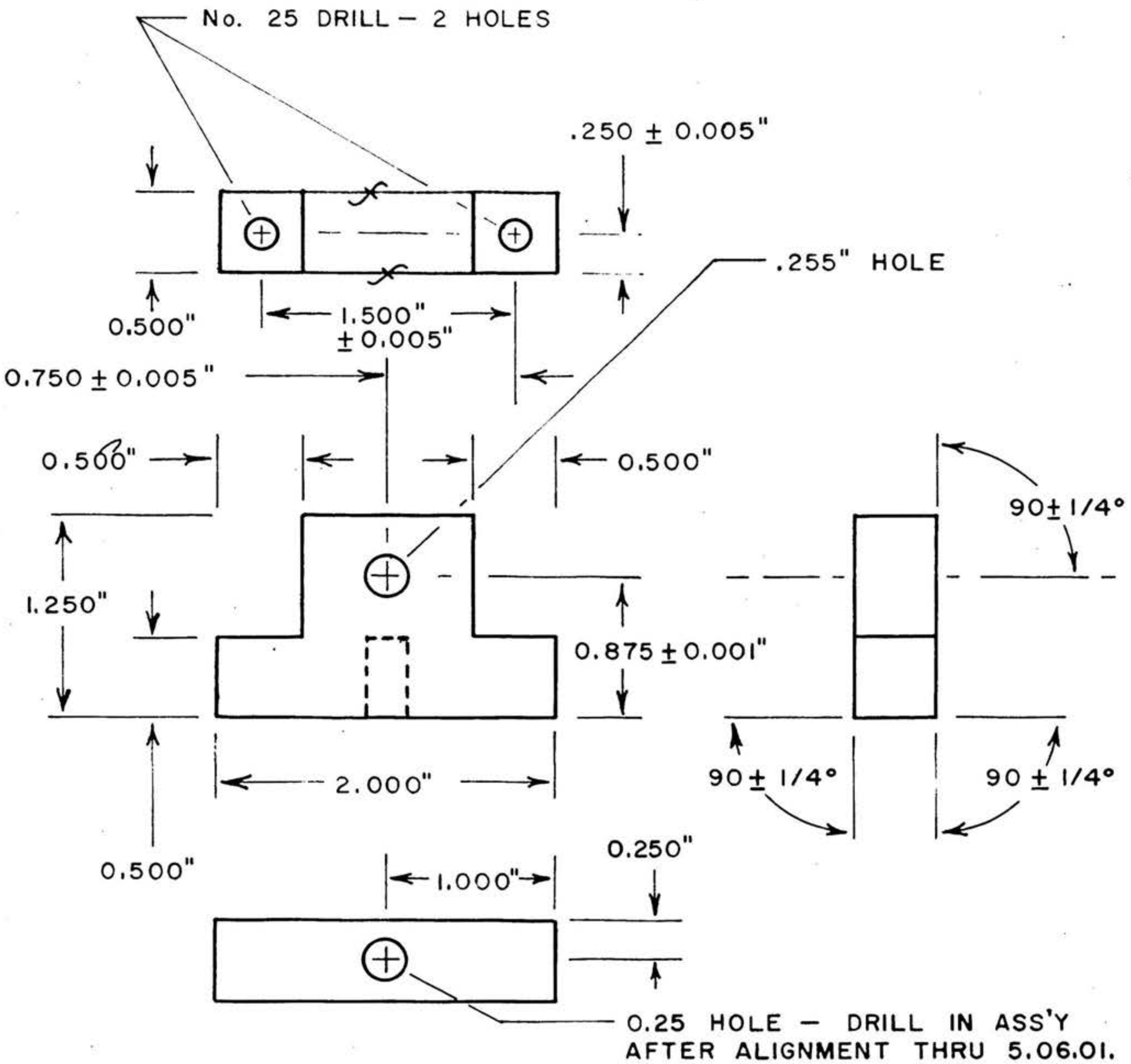
GUIDE TO HOLES:

A - #11 DRILL HOLES.
C - 0.250" HOLE.
B - 8-32 TAP.
D - 8-32 TAP.

ANGLE BETWEEN LINES DEFINED BY B & D HOLE CENTERS = 90 ± 1/4°.
CENTER D HOLE MUST BE WITHIN 0.005" OF LINE BETWEEN D HOLES.

TOL - ± 0.015" EXCEPT AS NOTED.
MATERIAL - 24-S ALUMINUM

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 11-15-58 REV. A	BASE PLATE
	5.06.01



TOL – ± .015" EXCEPT AS NOTED. MATERIAL – .500" AL

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

JKH 11-15-58	SHAFT GUIDE
	5.06.03

Drawing 5.07.00-A
Grating Drive Unit
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.07.00	5.07.00-A 5.07.00-B 5.07.00-C 5.07.00-E	(A)	Grating Drive Unit
	5.07.00-H	(B)	Electrical Schematic
5.07.01	5.07.01	(1)	Flange Assembly
5.07.02S1	None	(C)	Motor Box, 6" x 6" x 6" Steel Utility
5.07.03S1	None	(D)	(S1) Toggle Switch, DPTT, 5 Amp
5.07.04	5.07.04 5.07.20-2	(2)	Collar
5.07.05	5.07.05	(2)(E)	Scale Wheel
5.07.06	5.07.06	(2)	Counter Drive Screw
5.07.07	5.07.07		Counter Block
5.07.08S2	None		Screw, hex head, brass, 1", 8-32
5.07.09S1	None		Lock Nut, hex, brass, 8-32
5.07.10S2	None		(S2 & S3) Limit Switch, SPDT, ACRO Type RD-5L 1106.
5.07.11	5.07.11 5.07.24	(F)	Frame Side Plate
5.07.12	5.07.12		Top plate
5.07.13	5.07.13		Bottom plate
5.07.14	5.07.14	(G)	Motor Mount Plate
5.07.15S2	None		Screw, flat head, steel, 3/4", 1/4"-20

Part No:	Dwg. No:	Note:	Description:
5.07.16S2	None		Screw, flat head, steel, 2-1/2", 1/4"-20
5.07.17S2	None		Hex nut, steel, 1/4"-20
5.07.18S14	None		Screw, flat head, steel, 1", 10-24
5.07.19S1	None		Shaft, 11.65", 0.250" polished steel drill rod
5.07.20-2	5.07.04 5.07.20-2		Limit switch mounting block
5.07.21S4	None		Screw, round head, brass, 2", 8-32
5.07.22S4	None		Nut, hex, brass, 8-32
5.07.23S4	None		Lock washer, shake proof, #8
5.07.24	5.07.11 5.07.24	(F)(4)	Frame side plate
5.07.25S2	None		1/2" rubber grommet for 1/4" wall
5.07.26S1	None		(p-1) plug, 11 pin octal type, Ampherol type 86-PM-11.
5.07.27S6	None		Set screw, Allen head, steel 1/4", 6-32
5.07.28S1	None		(M-1), Drive Motor, Borg model 1007-4Sy, 5 stage, 1800 rpm-1 rpm, 8.9 in-oz torque.
5.07.29S1	None		(C-1) Motor Starting Capacitor for drive motor (M-1)

FABRICATION NOTES:

(1) Seal Installation:

Assemble part as indicated by drawing 5.07.01. Insert a 0.250" shaft through vacuum seal and center hold while soldering seal in place. Seal is Vacuum Research Company type S101 high vacuum seal. Solder joint must be leak free for high vacuum.

CAUTION: Remove rubber washers from inside seal while soldering.

Hole A:

The two concentric circles at (A) indicate the location of the "O" rings pump out. Drill a 1/16" hole through the flange at the point indicated. Counter bore to a 1/8" diameter to a depth of 1/2" from the unfinished side of the flange. Insert a 1-1/4" length of 1/8" copper tubing and solder in place with soft solder.

(2)

Equip with set screws (5.07.28S6).

ASSEMBLY NOTES:

(A)

Assemble unit in accordance with assembly drawings 5.07.00-A, B & C and with the following assembly notes. Shaft must turn freely after assembly.

(B)

Wire electrical circuit as indicated in drawing 5.07.00-H. Use AWG #18 thermoplastic insulated wire. Route wires running from motor box to limit switches through hole (D) in plate 5.07.14. Route cable from drive unit to control unit through hole (E) in plate 5.07.14. Install rubber grommets (5.07.25S2) in both holes. Equip unit with a 25 foot long, 10 wire cable of AWG #18 thermoplastic insulated copper wire. Terminate this wire at five pin connector (5.07.26S1) and six pin connector (5.07.27S1) as indicated by drawing 5.07.00-H.

(C)

Drill mounting holes at edges of motor mounting plate (5.07.14) and mount box so that the plate forms one side of closed box.

ASSEMBLY NOTES (Cont'd):

(D)

Mount switch in (C) hole in motor mount plate so that handle is outside of box 5.07.02S1.

(E)

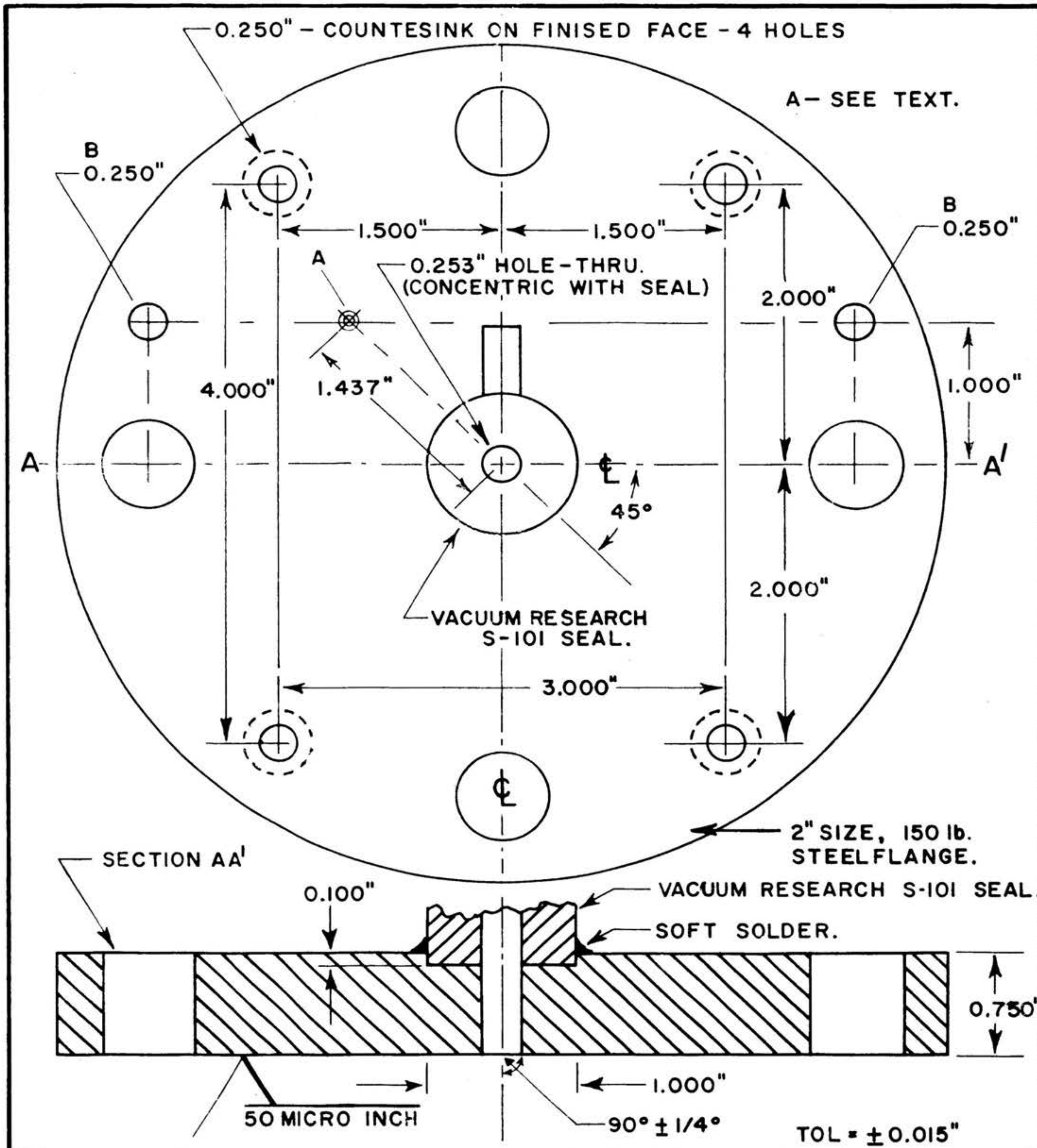
Adjust scale wheel so that zero mark is at index point when counter block (5.07.07) mark is at one of the scale markers before tightening set screws. Scale wheel must be positioned to turn freely in the slot in the top plate (5.07.12).

(F)

Attach frame side plates to flange assembly (5.07.01) with screws 5.07.16S2 and nuts 5.07.17S2 at top and screws 5.07.15S2 at bottom.

(G)

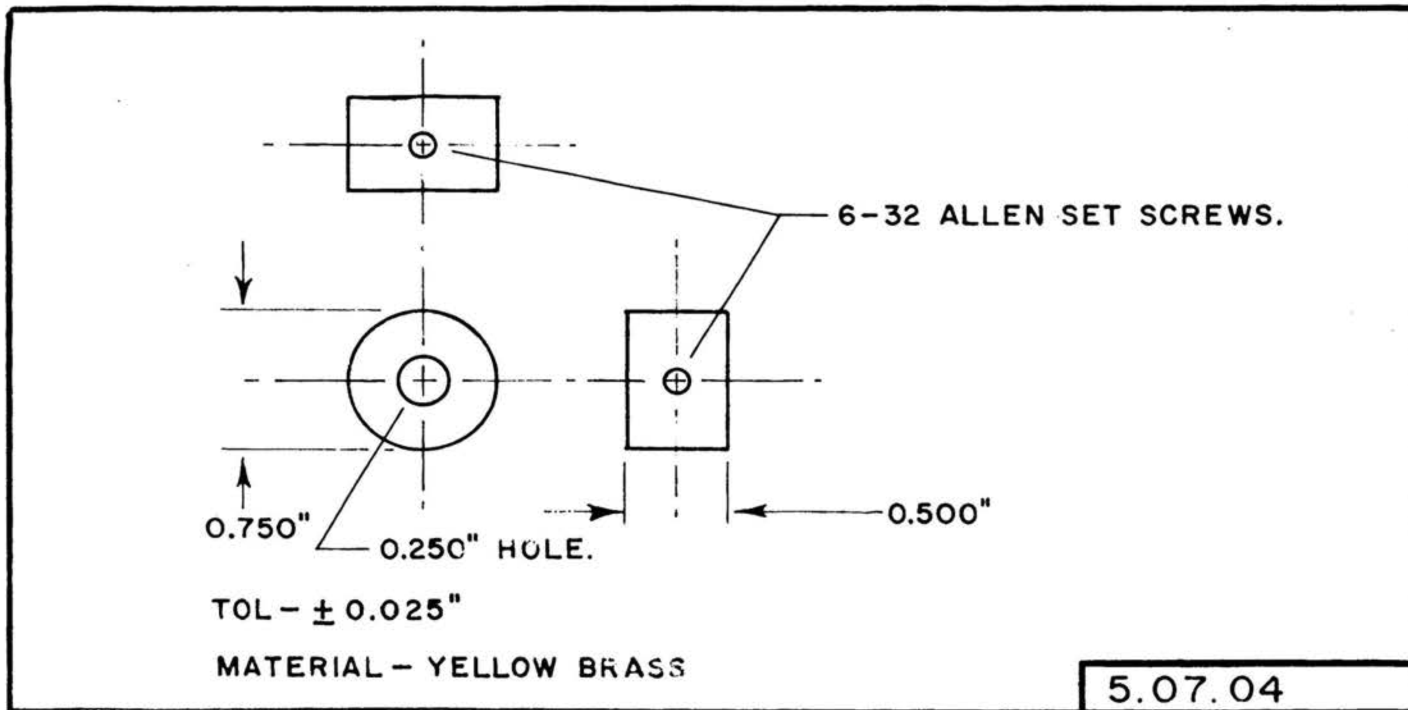
Drill as necessary to mount drive motor.

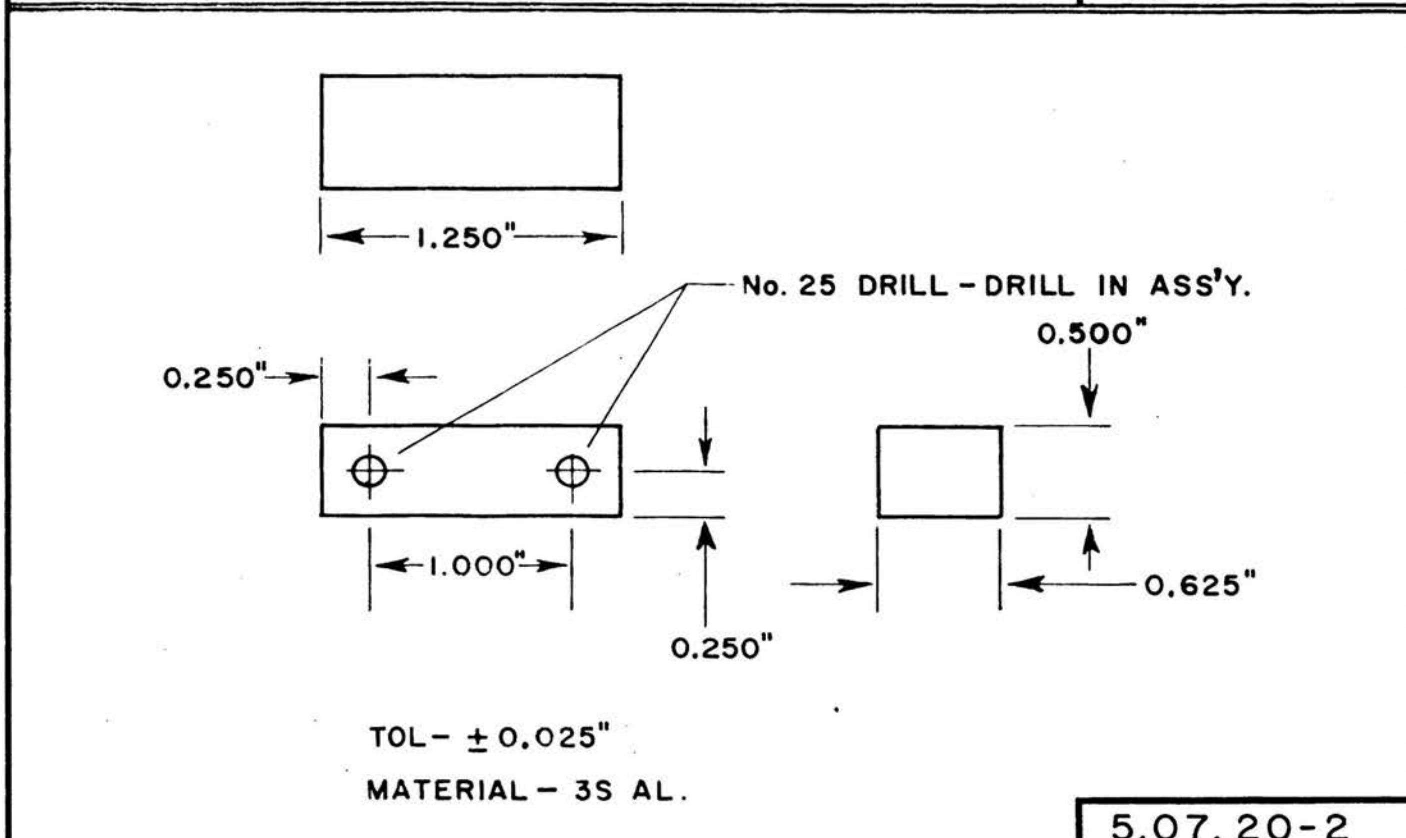


M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

	FLANGE ASSEMBLY
	5.07.01

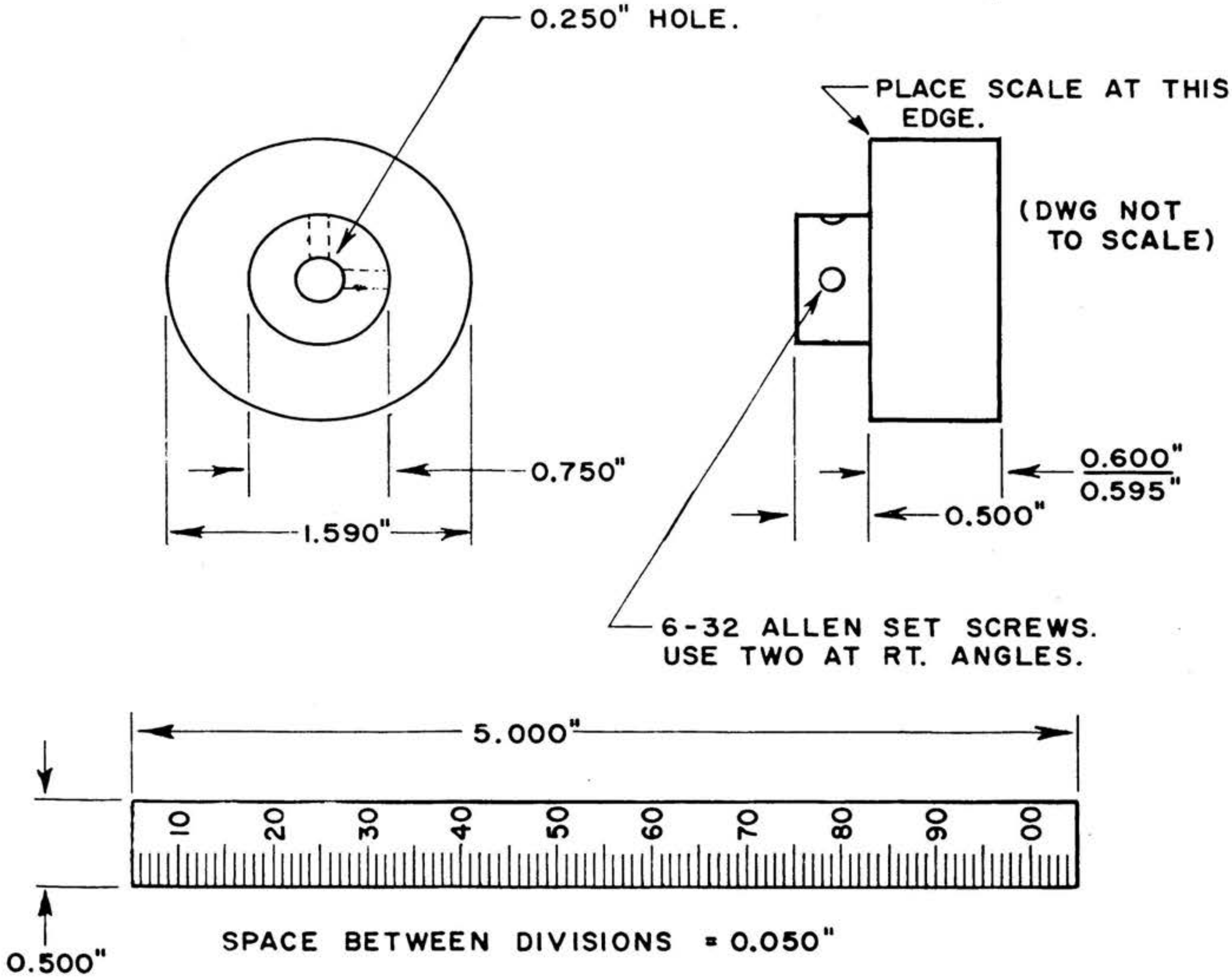




M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

COLLAR	SWITCH MOUNT BLOCKS
5.07.04	5.07.20-2

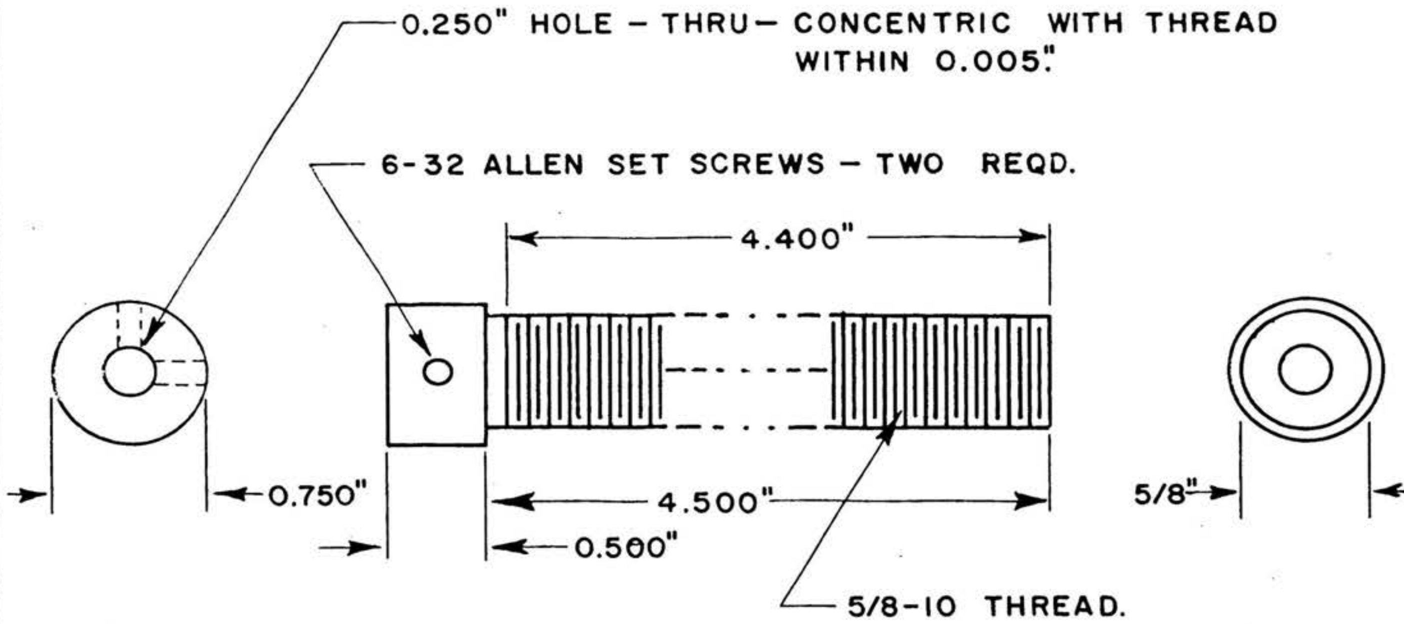


NOTE — CEMENT SCALE TO DRUM WITH CONTACT BOND CEMENT.

TOL - ± 0.015"

MATERIAL - YELLOW BRASS

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	SCALE WHEEL
	5.07.05



TOL – ± 0.025"

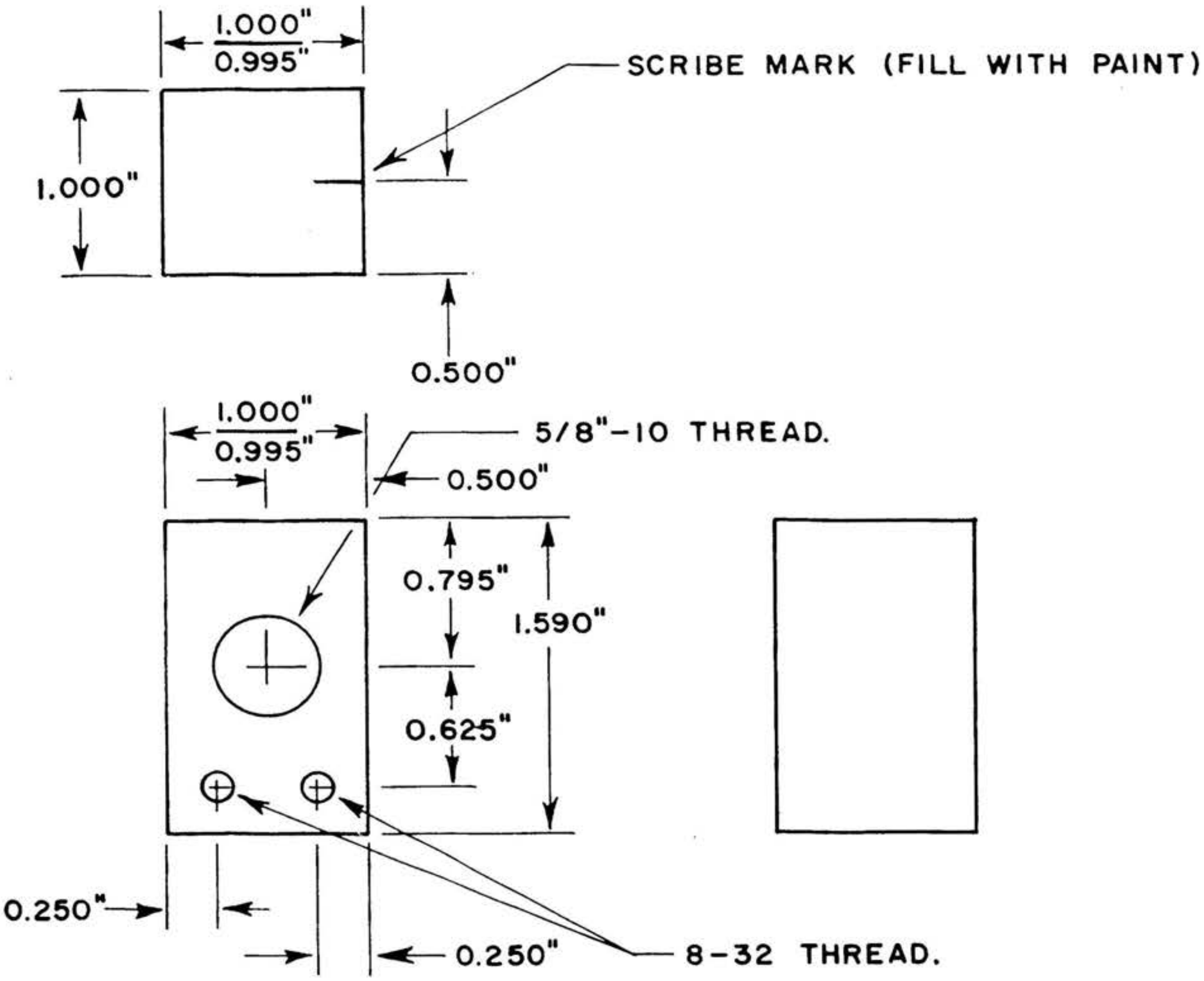
MATERIAL – YELLOW BRASS

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

COUNTER DRIVE SCREW

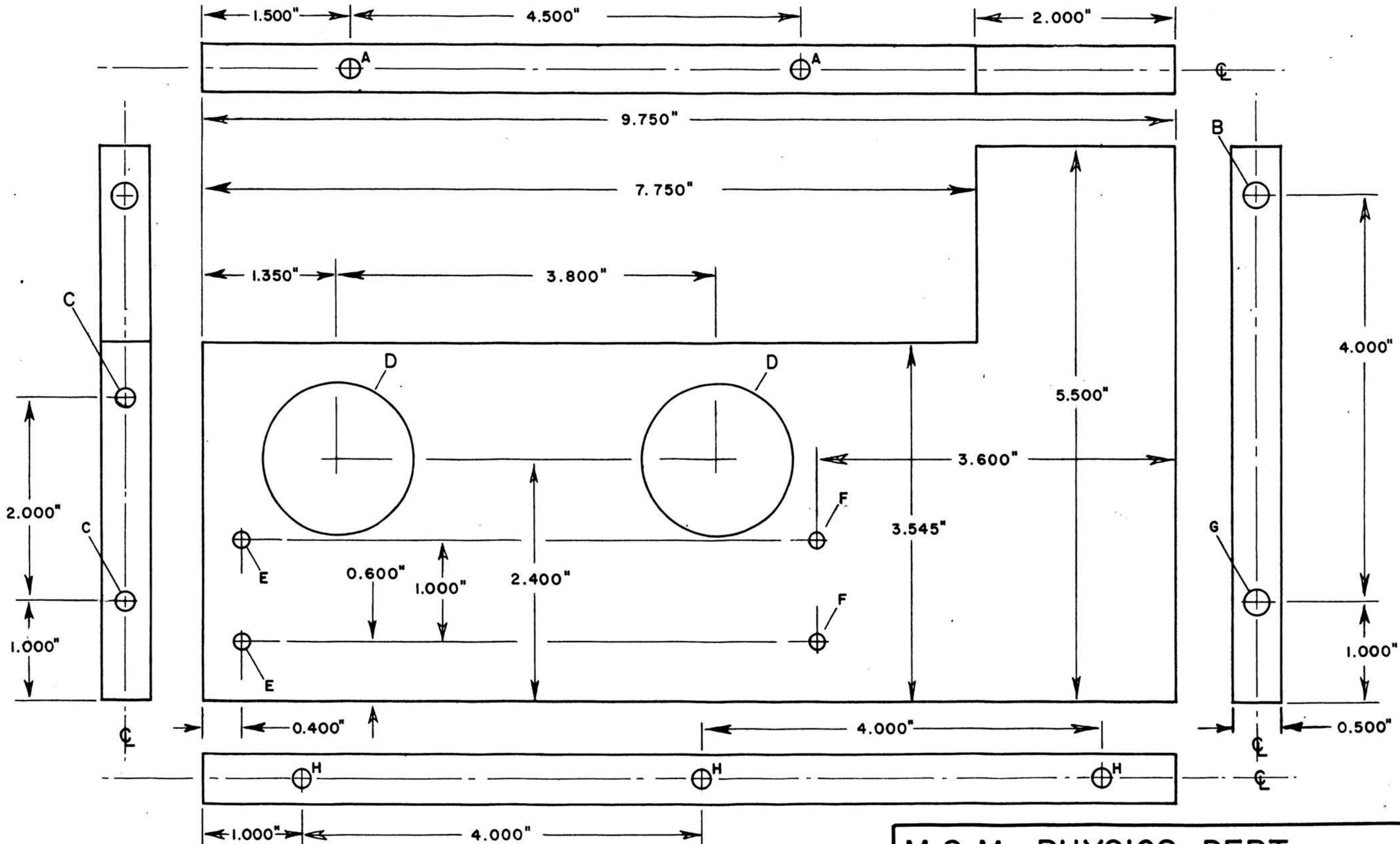
5.07.06



TOL - ± 0.015"

MATERIAL - YELLOW BRASS.

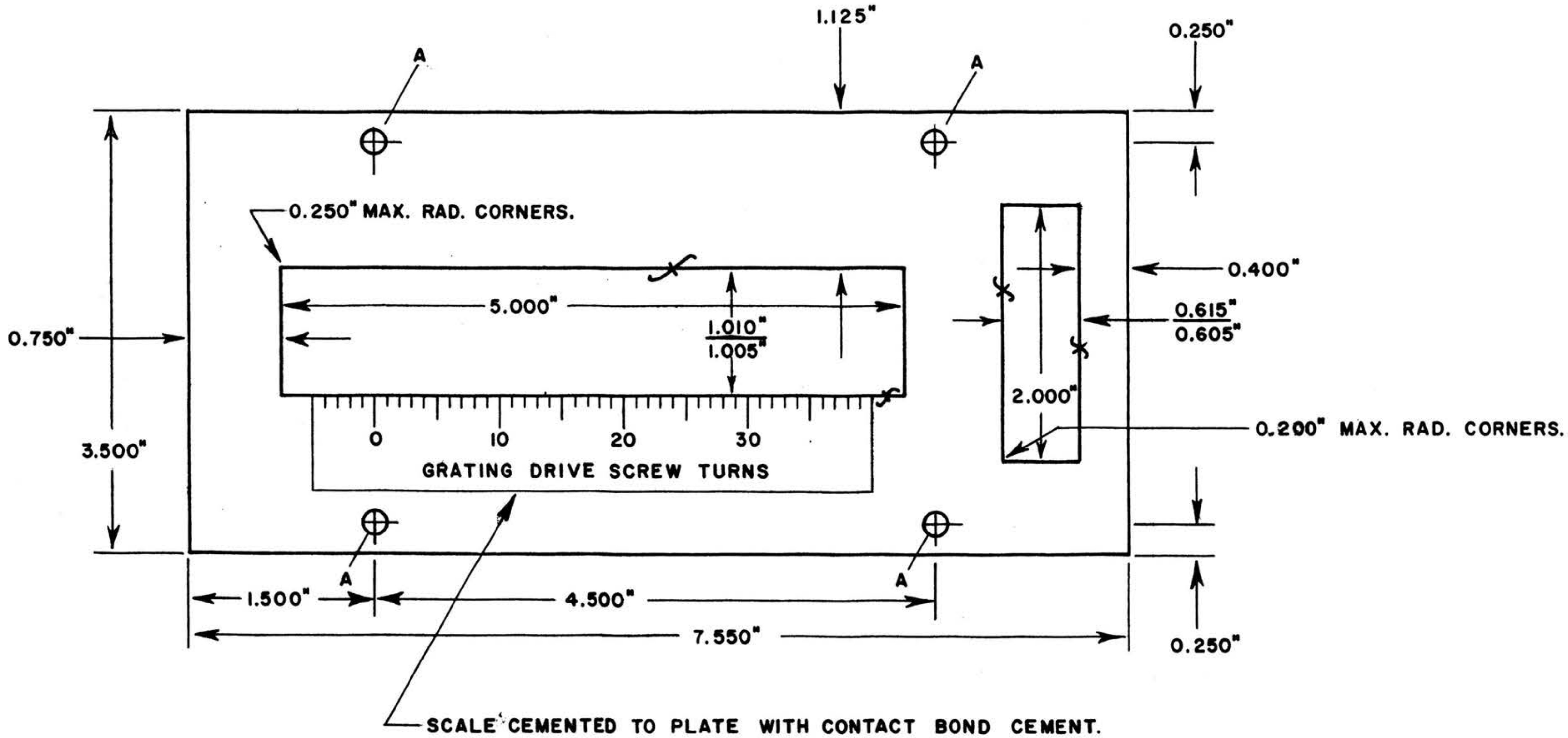
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	COUNTER BLOCK
	5.07.07



A - 10-24 TAP. (0.750".) - TRANSFER FROM 5.07.12 IN ASS'Y.
B - 0.250" HOLE - TRANSFER IN ASS'Y FROM 5.07.01.
C - 10-24 TAP. (0.750".) - TRANSFER IN ASS'Y FROM 5.07.14.
D - 1.500" HOLE.
E - No. 25 DRILL. (5.07.11 ONLY.)
F - No. 25 DRILL. (5.07.24 ONLY.)

G - 1/4-20 TAP. (0.750") - TRANSFER IN ASS'Y FROM 5.07.01.
H - 10-24 TAP. (0.750") - TRANSFER IN ASS'Y FROM 5.07.13.
TOL - ±0.015"
MAT. - 0.500" 3003-0 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
FRAME SIDE PLATE	FRAME SIDE PLAE
5.07.11	5.07.24

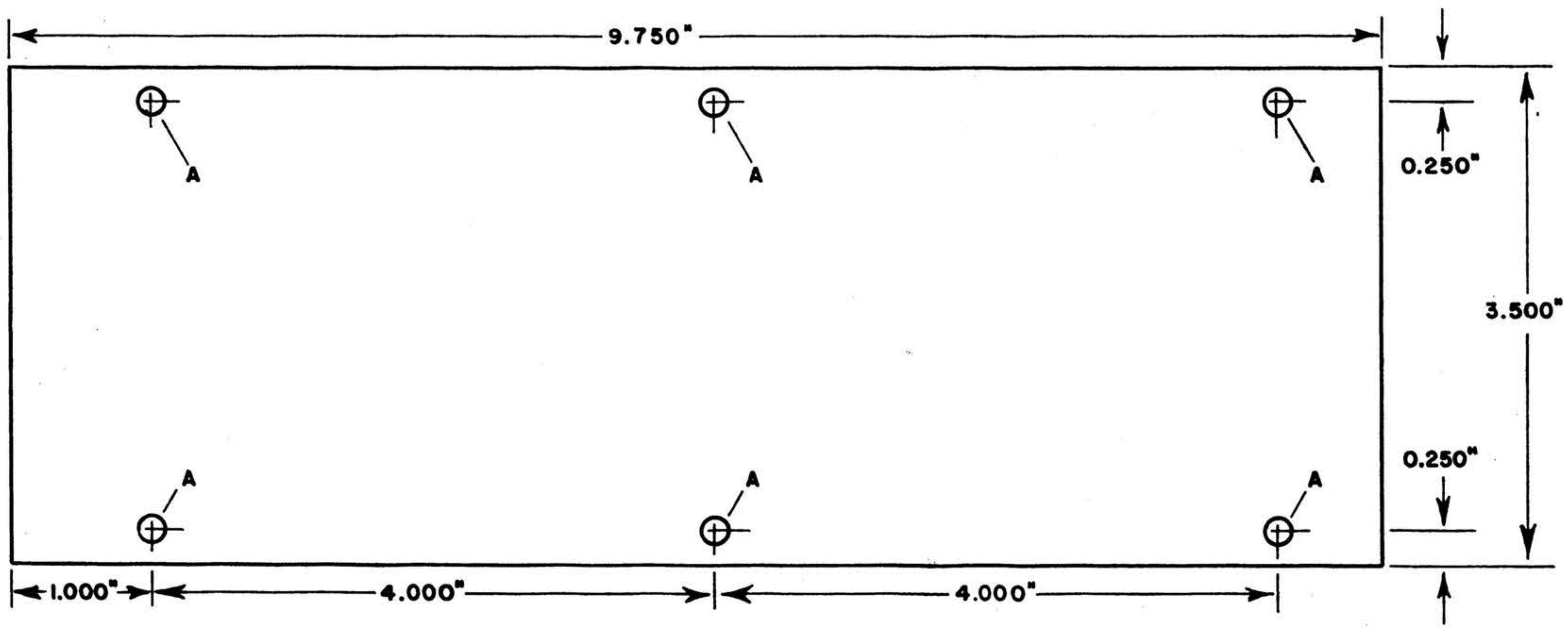


TOL - ± 0.015"

MAT. - 2024 T4 AL - 0.250" FLAT PLATE.

A - No. 11 DRILL - COUNTERSINK.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	TOP PLATE
	5. 07. 12

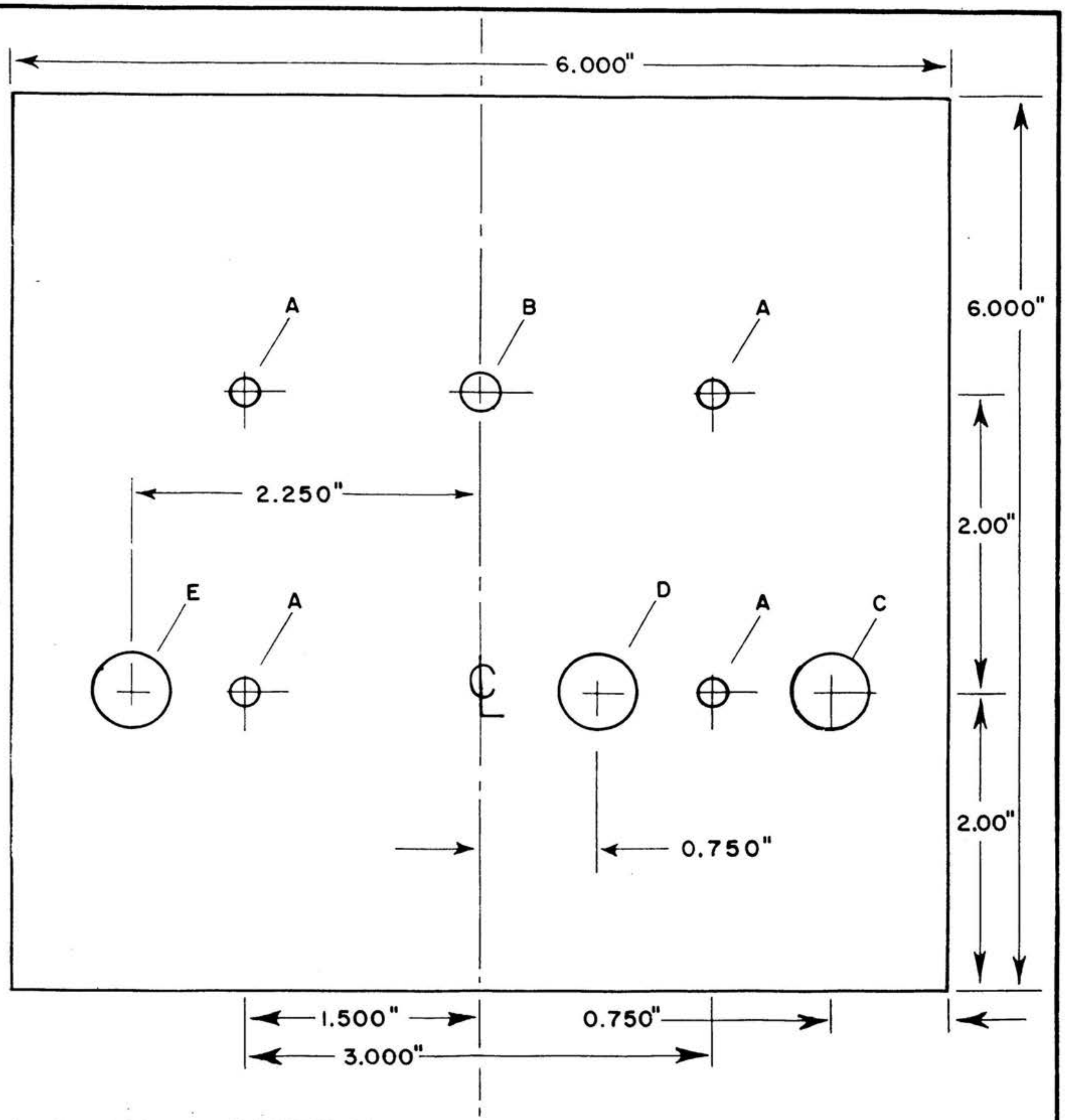


NOTE — PLATE IS 0.250" THICK.

A — No. 11 DRILL — COUNTERSINK

TOL — ± 0.015"
MATERIAL — 2024 T4 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	BOTTOM PLATE
	5.07.13



A – No. 11 DRILL – COUNTERSINK.
B – 0.253" HOLE.
C – 0.500" HOLE.

TOL – ± 0.015"
MATERIAL – 2024 T4 AL – (0.250").
PART IS 0.250" THICK.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	MOTOR MOUNT PLATE
REV. A.	5.07.14

Drawing 5.08.00-A
Grating Drive Shaft Assembly
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.08.00	5.08.00-A 5.08.00-B	(A)	Grating Drive Shaft Assembly
5.08.01S1	None		1.250", 0.250" dia. polished steel drill rod
5.08.02	5.08.02 5.08.03		Pin, index
5.08.03	5.08.03 5.08.02		Pin, index
5.08.04	5.08.04	(1)	Flange, coupling
5.08.05S2	None		Universal Joint - 1/4" Millen Type 39005
5.08.06S1	None		0.625", 0.250" dia. polished steel drill rod
5.08.07	5.08.07	(2)	Slider coupling
5.08.08S3	None		2.500", 0.250" dia. polished steel drill rod
5.08.09	5.08.09	(2)	Holder, coupling rod
5.08.10S7	None		1/8", 6-32 Steel Allen Set Screws

FABRICATION NOTES:

(1)

Drill the index pin holes in coupling flange 5.08.04 with part 5.08.04 clamped face to face with part 5.03.08. Insert a 0.250" shaft through center holes to insure correct alignment of the center holes during and after drilling.

(2)

Clamp parts 5.08.07 and 5.08.09 face to face while drilling the holes for parts 5.08.08. These holes must be drilled parallel so that part 5.08.07 will slide freely on the coupling rods (5.08.08). After drilling, ream the two outside holes in part 5.08.07 to a diameter of 0.255" to provide a sliding fit over parts 5.08.08. Ream the center hole in part 5.08.07 to a 0.255" diameter to a 1.750" depth from the face to give a sliding fit over the center shaft (5.08.08). Leave the holes in part 5.08.09 at the 0.250" diameter.

ASSEMBLY NOTES:

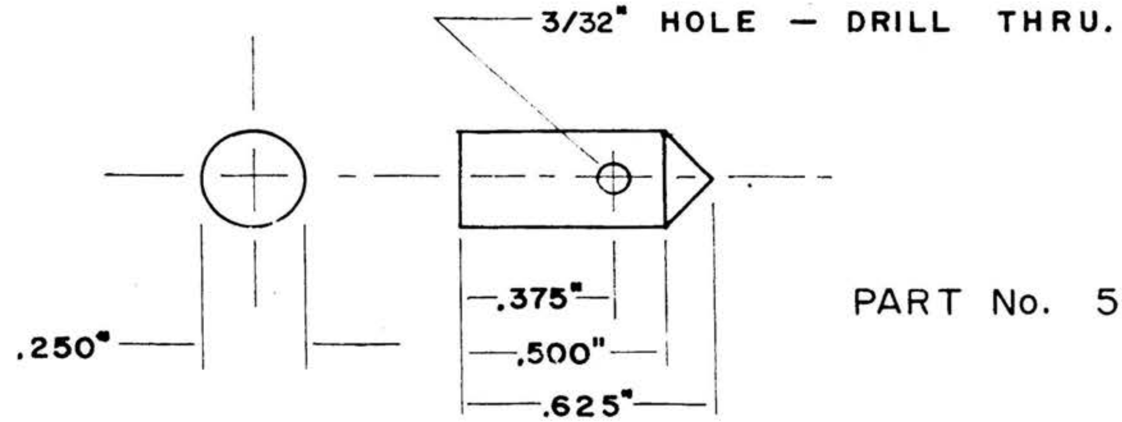
(A)

Assemble as indicated in drawing 5.08.00-B.

Part 5.08.07 must slide freely on rods 5.08.09. DO NOT LUBRICATE!

Drive shaft assembly must be free from backlash.

Tighten all set screws except those holding part 5.08.04 to shaft 5.08.01. This is done at installation.



PART No. 5.08.02

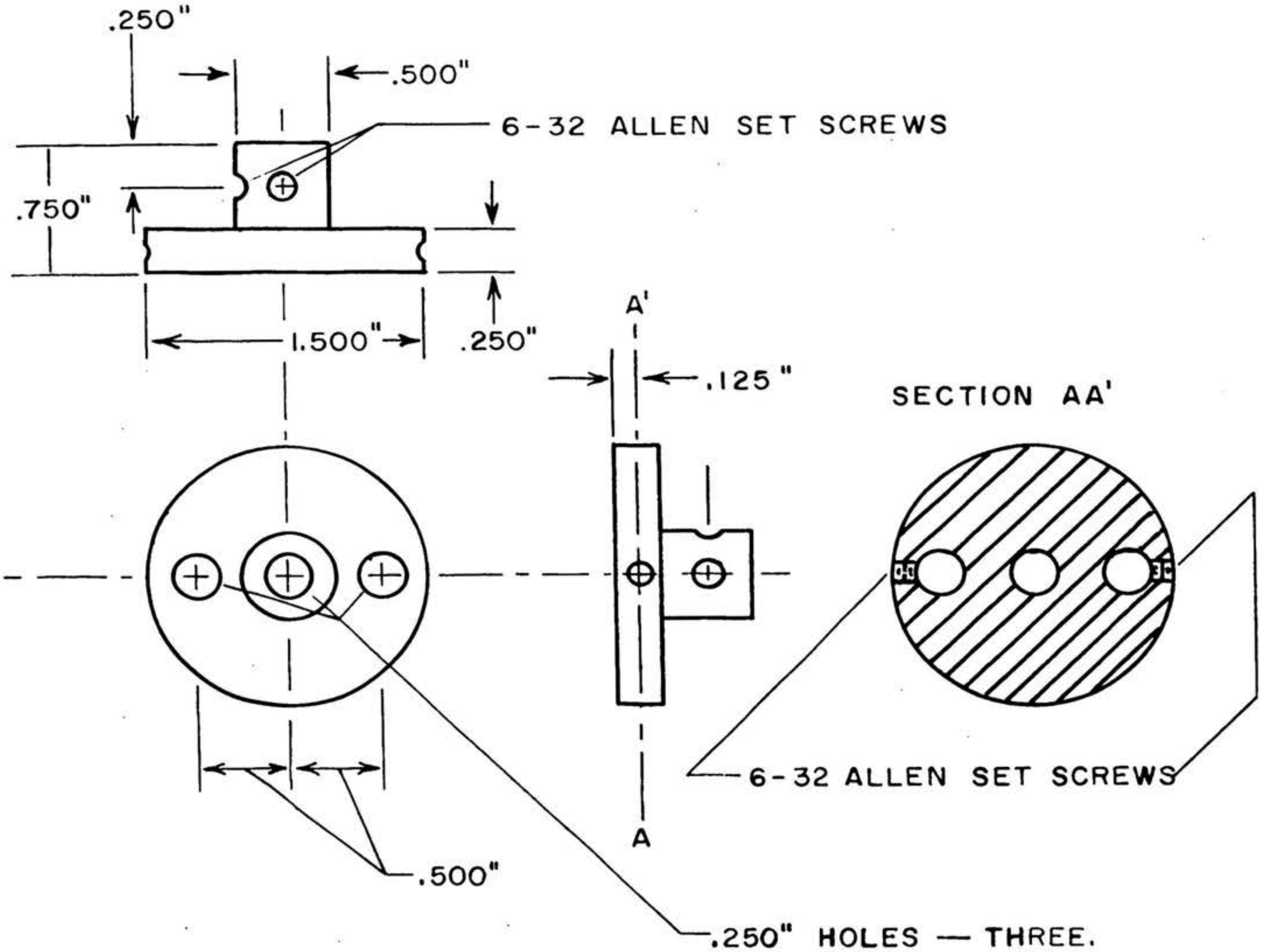
MATERIAL — .250" STEEL DRILL ROD.

TOL — ± .015"

DOUBLE SCALE.

NOTE — PART 5.08.03 IS IDENTICAL TO 5.08.02 EXCEPT THAT THE 3/32" HOLE IS OMITED IN 5.08.03.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 11/5/58	PINS, INDEX
	5.08.02 & 5.08.03

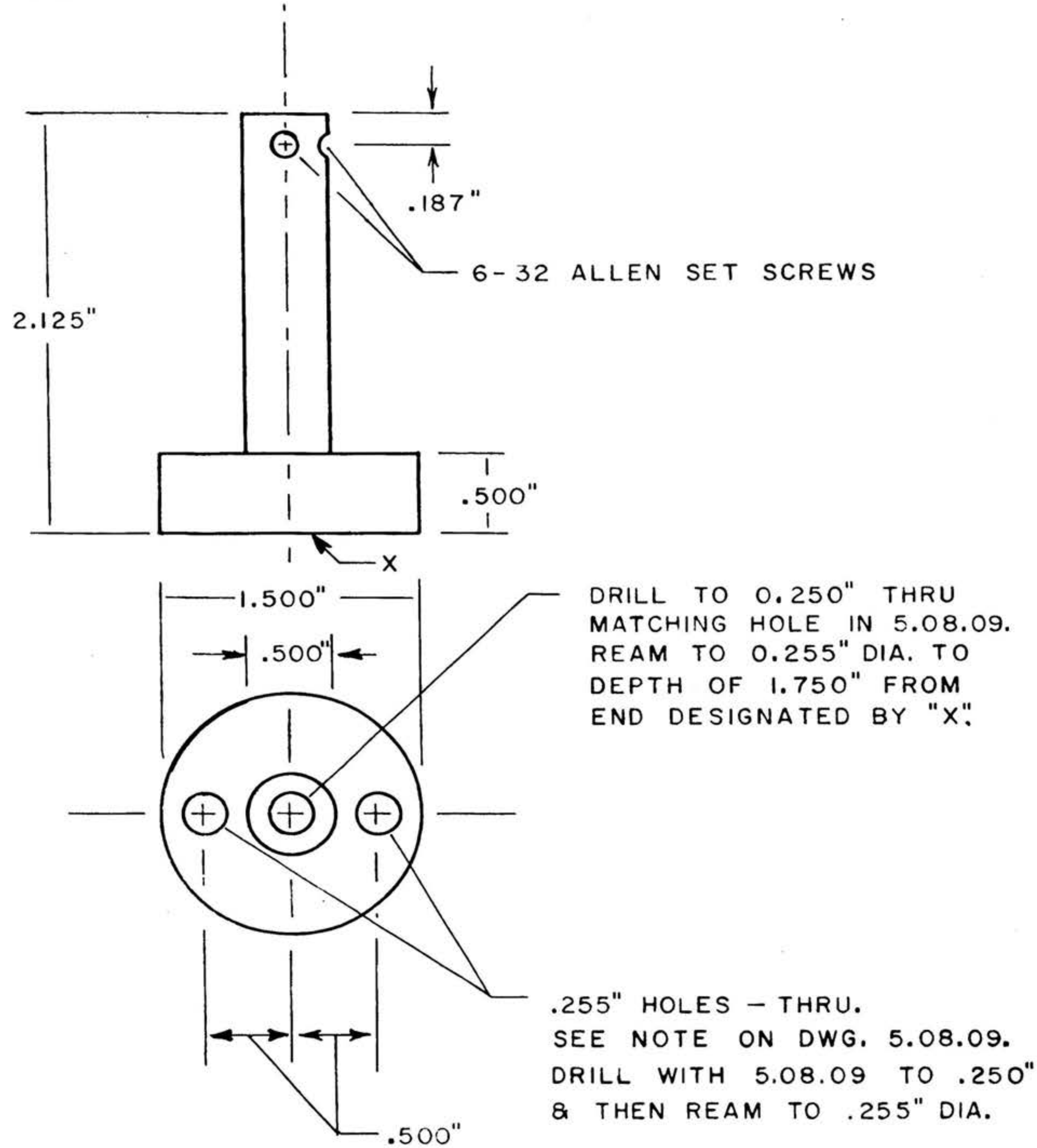


HOLES MUST BE PARALLEL
AND MATCH THE HOLES
IN PART 5.03.08.
CLAMP 5.08.04 & 5.03.08
TOGETHER FOR DRILLING.

FULL SCALE

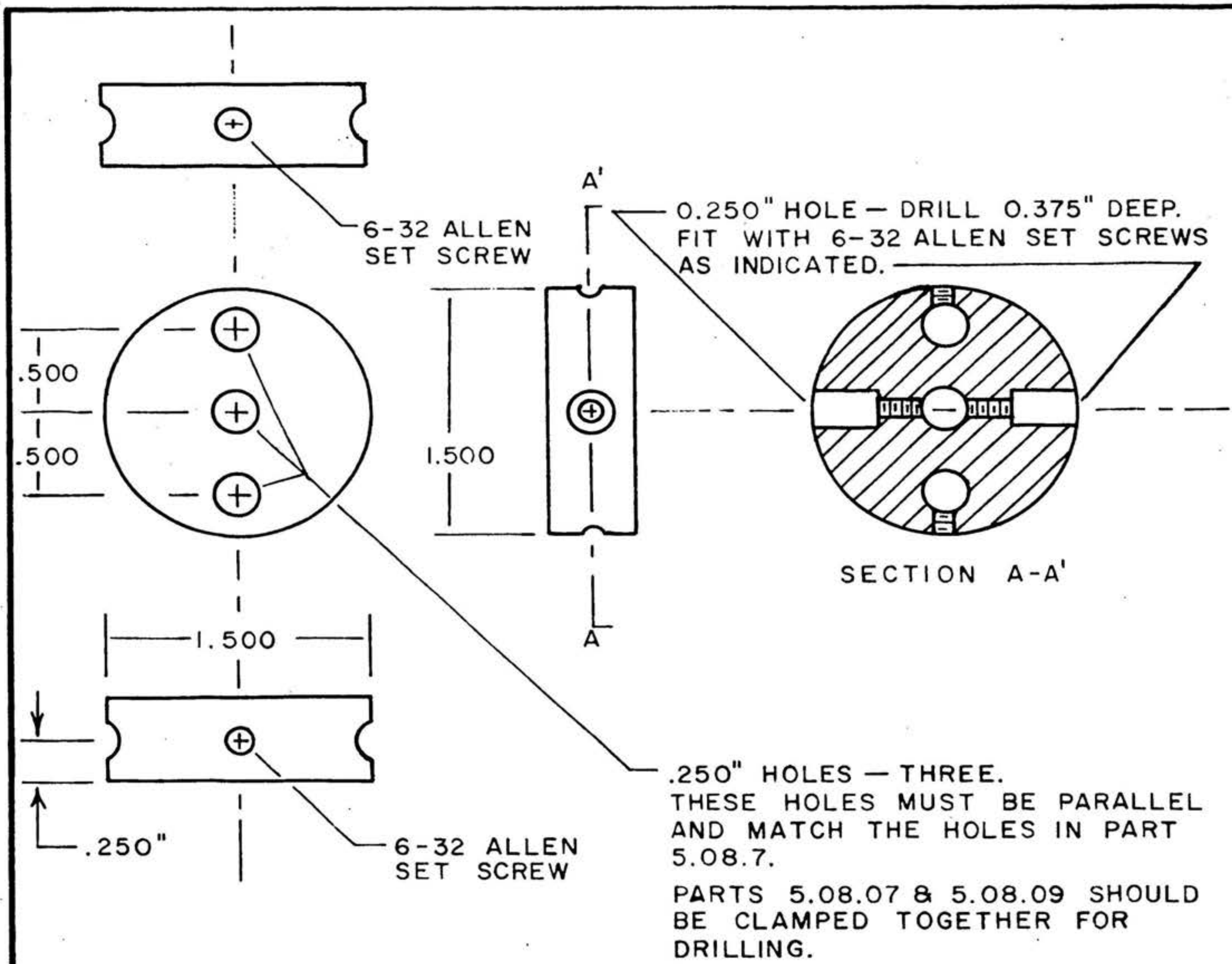
TOL – ± .015"   MATERIAL – 1.500" BRASS ROD

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 11-5-58	FLANGE, COUPLING
	PART No. 5.08.04



TOL: ± 0.015"
MATERIAL – 1.500" BRASS ROD

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 10/30/58	SLIDER, COUPLING
	5.08.07



MATERIAL: 1.500" BRASS ROD

TOL: ± .015"

— FULL SCALE —

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 10/29/58	HOLDER, COUPLING ROD
	5.08.09

Drawing 5.09.00A
Grating Drive Control Unit
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.09.00	5.09.00A 5.09.00B 5.09.00F	(A)	Grating Drive Control Unit
	5.09.00H	(B)	Electrical Schematic
5.09.01S1	5.09.00B	(1)	Panel, 5-1/4" x 19" x 1/8" aluminum rack panel, grey crackle finish
5.09.02S1	5.09.00F	(2)	Chassis Base, 5" x 9-1/2" x 3", (ICA type 1565)
5.09.03S1	None		(L-1) Pilot Light Assembly, Green Jewel, Dialco type C432'
5.09.04S2	None		(L-2, L-3) Pilot Light Assembly Red Jewel, Dialco type C431
5.09.05S3	None		(L-1, L-2, L-3) Pilot light bulb, 115V candelabra base, GE type S6
5.09.06S1	None		(F-1) Fuse Holder, Littelfuse type 342001.
5.09.06S1	None		(F-1) Fuse, 5 ampere
5.09.07S1	None		(S-1) Switch, SPST toggle, 5 ampere
5.09.08S1	None		(S-2) Switch, DPTT toggle, 5 ampere
5.09.09S1	None		(P-1) Plug, 2 pole std. chassis mounting plug. Amphenol No. 61-M
5.09.10S1	None		(J-1) Socket, 11 contact, chassis mounting, Amphenol type 78-RS-11.

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
5.09.11S1	None		(J-2) Receptacle, 2 pole female, chassis mounting, Amphenol type 61-F
5.09.12S4	None	(C)	Nut, hex, steel, 8-32
5.09.13S4	None	(C)	Lock Washer, shakeproof #8
5.09.14S4	None	(C)	Screw nickel plated, steel, half oval head, 3/8", 8-32
5.09.15S2	None	(D)	Screw, steel, round head, 1/4", 6-32
5.09.16S2	None	(D)	Nut, Hex, steel, 6-32

FABRICATION NOTES:

(1)

Drill panel for parts and engrave as indicated in drawing 5.09.00B. Drill holes for chassis mounting screws (5.09.14S4) in assembly with chassis (5.09.02S1) positioned as indicated in drawing 5.09.00F.

(2)

Punch and drill chassis for parts as indicated in drawings 5.09.00B and 5.09.00F. Drill holes for front panel mounting parts in assembly with panel (5.09.01S1).

ASSEMBLY NOTES:

(A)
Assemble unit as indicated by drawings 5.09.00B and 5.09.00F.

(B)
Wire as indicated by electrical schematic drawing 5.09.00H. Use AWG No. 18 thermoplastic insulated wire.

(C)
Attach chassis to panel with these parts.

(D)
Use parts for mounting socket 5.09.10S1.

6.00.00: FILM HOLDER AND MASK

6.01.00: Design Requirements

6.01.01: Film Holder Capacity and Range

The film holder was required to accept either 35 mm roll film or 10.000 x 1.250 x 0.050 inch glass plates. Provision for forming either plate type to the focal circle with sufficient accuracy for either normal or grazing incidence was required. The minimum width of the film plate area was dictated by the 35 mm (1.380") film requirement; 1.400 inches was selected in order to provide adequate film edge clearance. In order to provide a 1/8 inch edge support for the 1.250 inch glass plates, the distance between the film support ledges (the usable film width) was set at one inch.

As an aid in alignment and focusing, both the grating normal and the central image were to be visible from behind the film holder with the backing band removed and a frosted glass plate installed in the film position.

From section 4.05.08, the lateral coordinates of the zero and 2.000 Å wavelength lines are 5.152 and -5.419. Hence, the active width of the film holder is 10.571 inches. Allowance of an additional 0.11 inch for alignment tolerance and one-half inch for the end tie blocks resulted in an overall film holder width of 11.680 inches.

The film holder is in approximately the proper position when the back side is along station line 60.000 and the narrow end is at position line -5.896.

6.01.02: Adjustments

Provision for independent adjustment of each end of the film holder to allow precise placement of the photo plate emulsion on the focal circle was required. Positive locking and accurate indexing to preserve these adjustments during removal and installation of the film holder were considered essential.

6.01.03: Film Loading

Removability of the film holder from the instrument for loading was desired. As such operations must be performed in darkness, a simple snap-in device for supporting the film holder was required. As removal of the large and cap is difficult and time consuming, provision for inserting the film holder through a smaller side access port was desirable.

6.01.04: Multiple Exposure Capability

Pump down time for the vacuum system being a major time element in use of vacuum spectrographs, a multiple exposure provision is desirable. Because of the inherent difficulties in changing film or plates without letting down to air, means of making a series of exposures on narrow strips of the same plate was selected. In view of the small astigmatism (see section 4.05.10), it is necessary to move the film vertically between exposures to expose a new strip. Consequently, a mechanism to accomplish this task is required. Using a mask directly in front of the film or plate with an 0.2 inch opening, it is possible to make four exposures on each plate. This requires a total vertical movement of 0.8 inch or $\pm$ 0.4 inch from the center position. The center of the mask opening is at the same level as the grating center.

<u>6.01.05</u>: Mask Requirements

Access to the film holder from the side port required that provision be made for moving the mask away from the film holder. As the mask was to be used as a reference for locating the focal circle in the absence of the film holder a positive means for locking it in its proper position was required. Provision for adjusting the mask position in relation to the focal circle was also desired.

If the film holder may be raised or lowered 0.4 inch from the center position and the usable portion of the film is one inch wide, the total mask height must be 1.8 inches. However, it is desirable to use the mask as a shutter. This requires an additional 0.6 inch of mask height. Allowing an additional safety margin 0.3 inch at each end results in a total mask height of 3.0 inches. Hence, the bottom of the mask will be at W.L. -1.500 and the top at W.L. 1.500.

The focal circle radius is 29.528 and the thickness of the film holder face plate is 0.094 inch. Allowing for a 0.031 inch holder-mask separation results in a mask outside radius of 29.403 inches. Hence, when properly adjusted, the mask surface will be 0.125 inch from the focal circle.

As the mask must be set inside the focal circle, its length must be 0.563 inch less than that of the film holder or 11.118 inches. When properly placed, the back edge of the mask form plate should be at S. L. 57.000.

6.02.00: Film Holder and Mask Description

6.02.01: Film Holder, Positioner and Mask Assembly Views

The complete film holder, film positioner and mask assemblies are shown together by assembly drawings 6.00.00-B, C & E (figures 6.02.01-A, B & C). The positioning assembly is shown in figure 4.04.05-A.

6.02.02: Film Holder (Assembly 6.01.00)

The film or glass plate is formed into a Rowland Circle segment and held in place by a removable film holder (6.01.00). See figure 6.02.01. This holder consists of the focal circle form assembly and a film backing band (6.01.05). The form assembly primarily consists of two precisely milled one-half inch cast aluminum form plates (6.01.01 & 6.01.11) having a segment of a 75 cm radius circle milled into one edge. These plates are separated

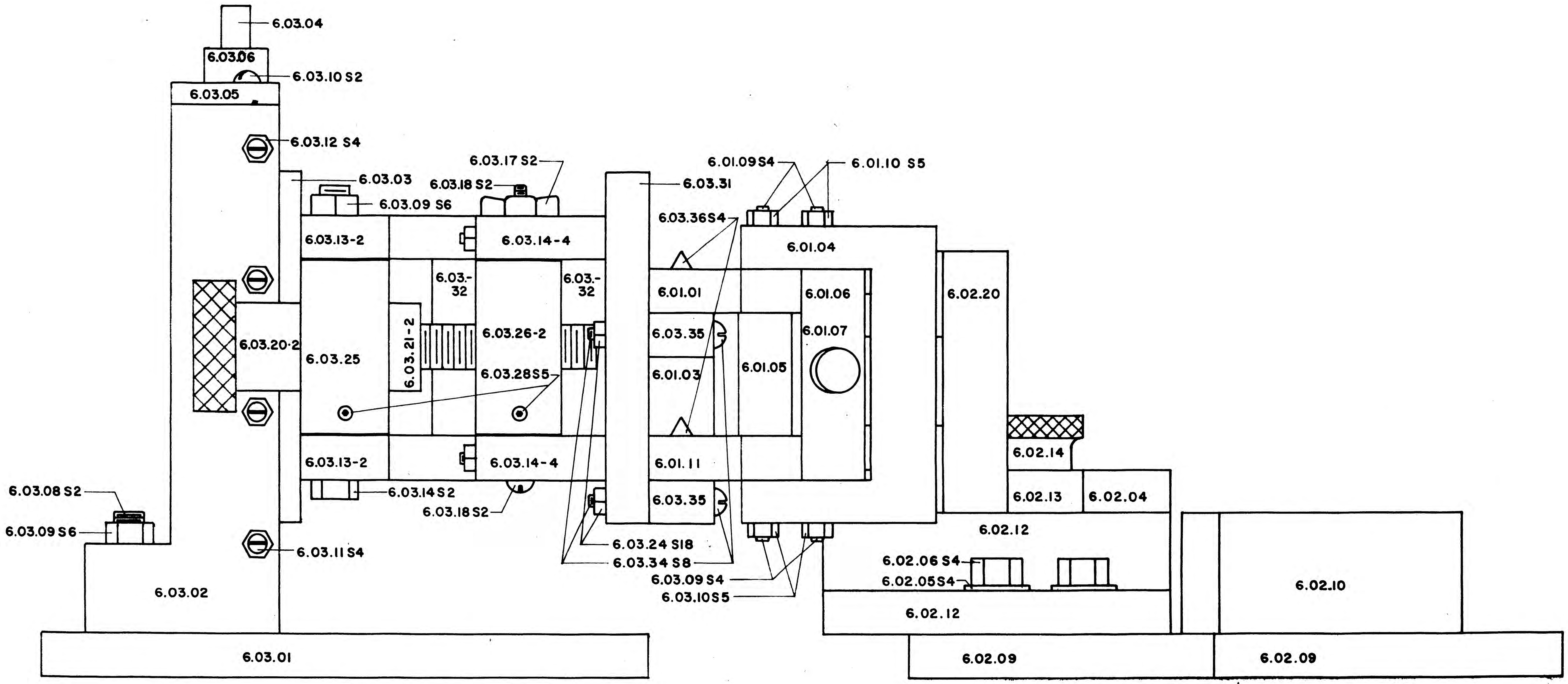


FIGURE 6.02.01A

M.S.M. PHYSICS DEPT.
VACUUM SPECTROGRAPH
FILM POSITIONER, HOLDER, & MASK ASSEMBLIES
6.01.00, 6.02.00 & 6.03.00 — DRAWING 6.00.00-B

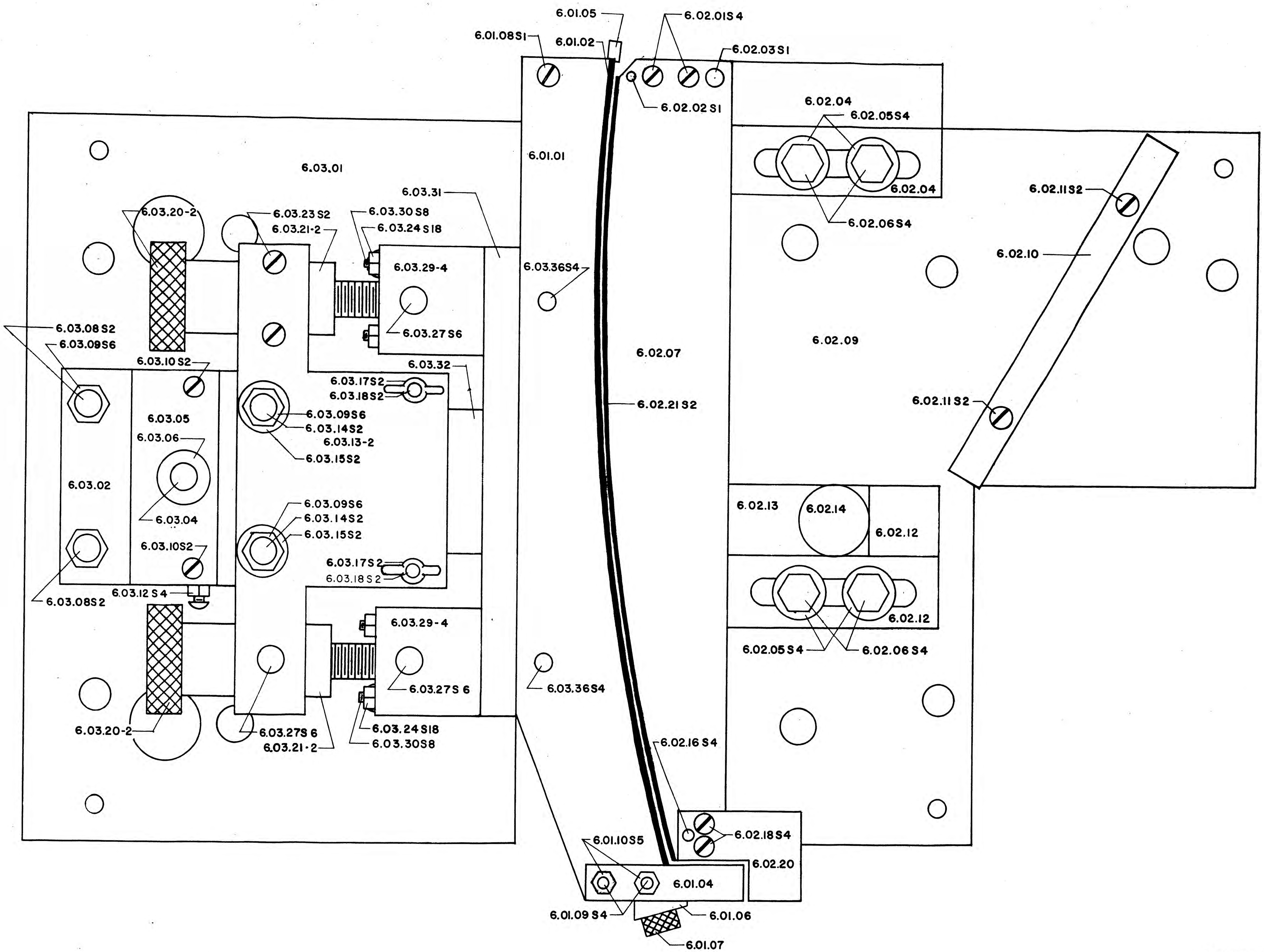


FIGURE 6.02.01 B

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
FILM POSITIONER, HOLDER & MASK ASSEMBLIES	
6.01.00, 6.02.00 & 6.03.00	DRAWING 6.00.00-C

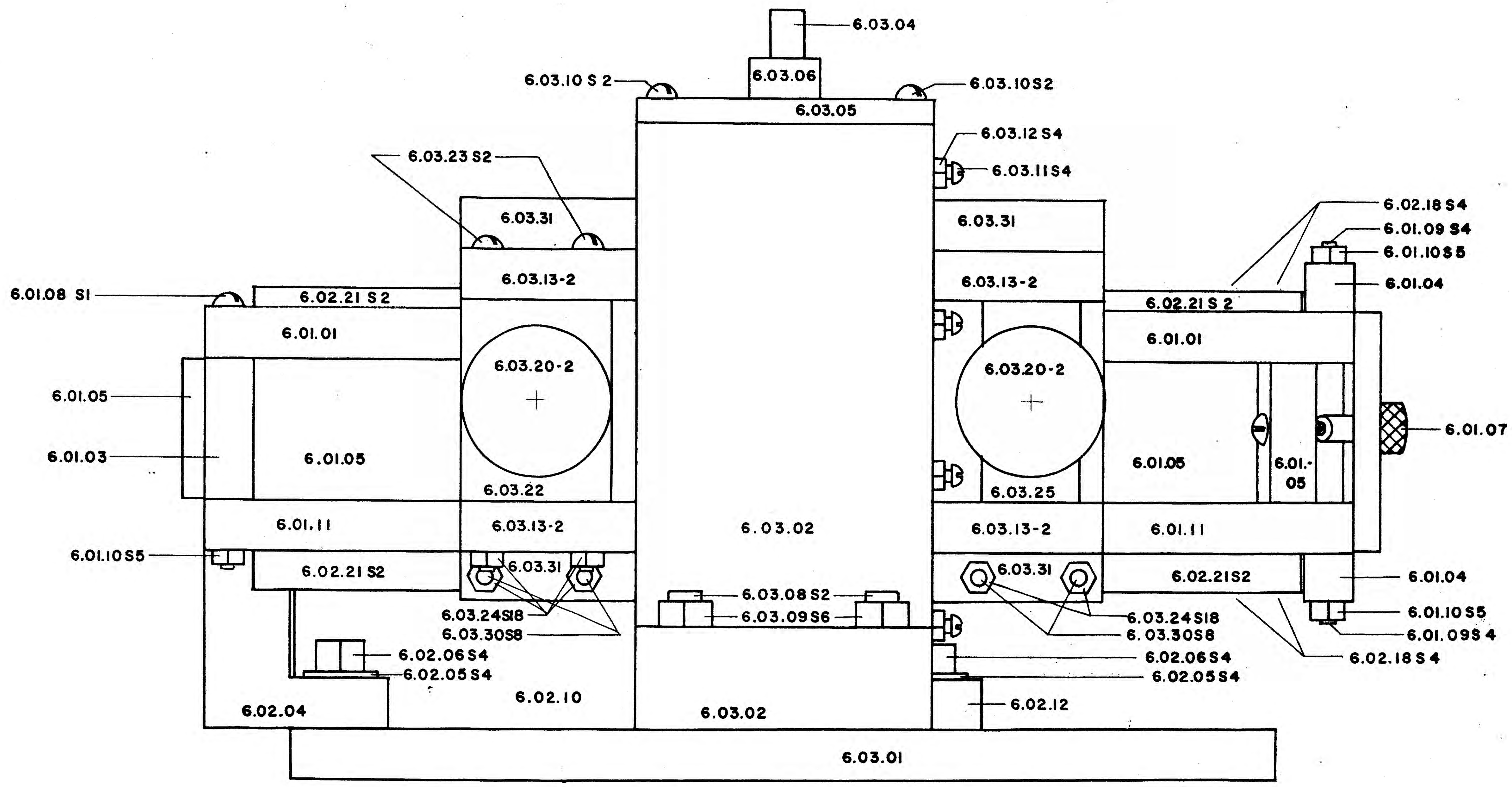


FIGURE 6.02.01C

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
FILM POSITIONER, HOLDER & MASK ASSEMBLIES	
6.01.00, 6.02.00 & 6.03.00	DRAWING 6.00.00 E

1.400 inch by spacer blocks 6.01.03 & 6.01.04. A face plate (6.01.02) with a 1.000 x 10.800 inch slot in it held against the Rowland Circle segment of the form plates serves as a support for the edges of the film or plate. The film or plate is held tightly against the face plate by the backing band, thus forming the front surface of the film or plate to a precise 75 cm circle segment. Because the front (emulsion) side of the film or plate is in direct contact with the focal circle reference, the holder is capable of accepting different thickness films and plates without defocusing. The backing band is held in place under tension by clamp block 6.01.06 and thumbscrew 6.01.07. The backing band is secured by a hook at the opposite end.

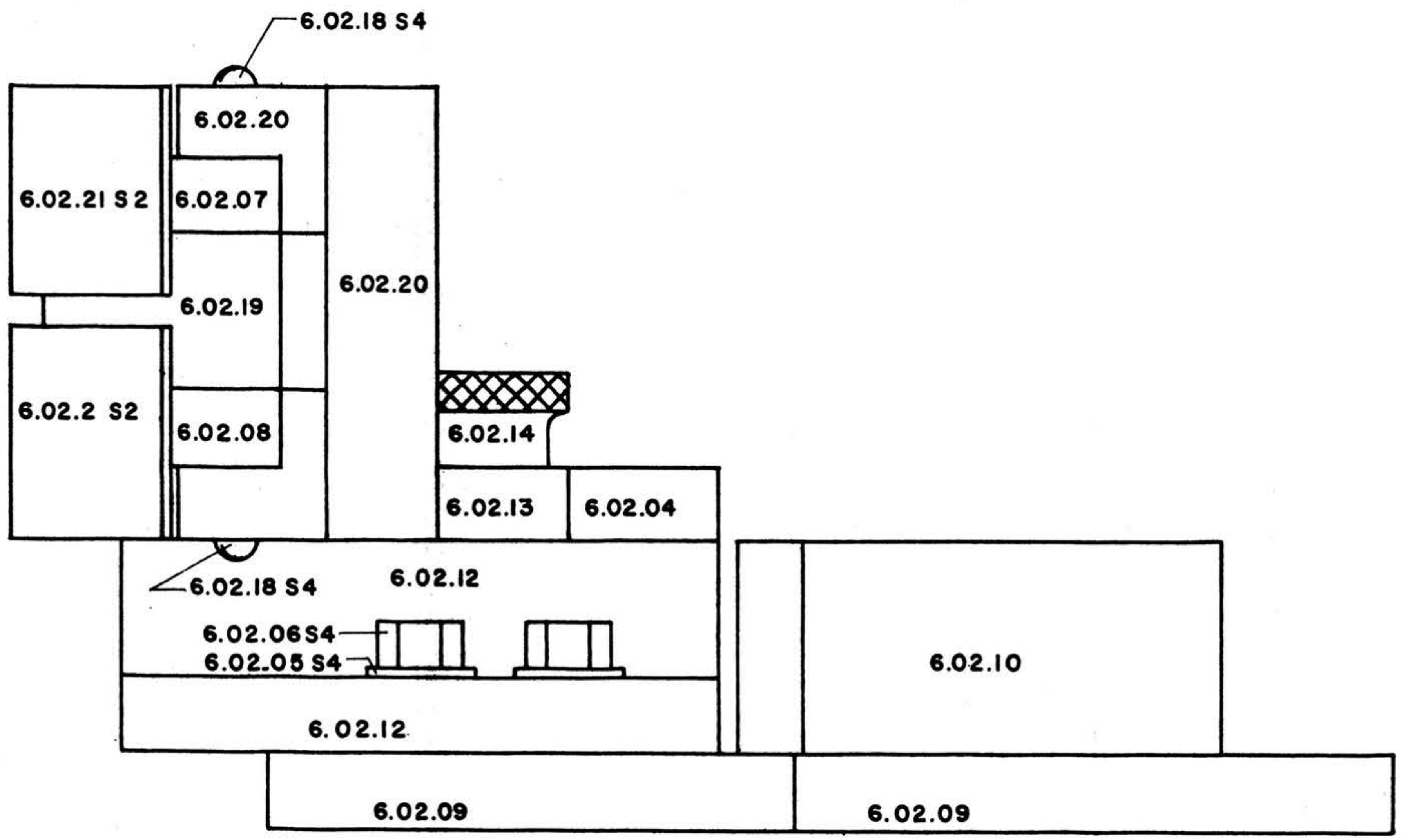
The film holder hooks to the film positioner assembly (6.03.00) by four 0.250 inch pins (6.03.36S4) firmly attached to the support blocks (6.03.35-2). It may be removed by lifting it vertically from the pins.

6.02.03: Mask (Assembly 6.02.00)

Side and front views of the mask assembly are shown by figures 6.02.03 A & B (assembly drawings 6.02.00-B & E). A top view is shown by figure 6.02.01-B (dwg. 6.00.00-C).

The mask proper consists of two 0.063 inch thick plates (6.02.21S2) supported by and formed into a circle segment by form plates 6.02.07 and 6.02.08. The two mask plates are separated so as to leave a horizontal 0.2 inch slit

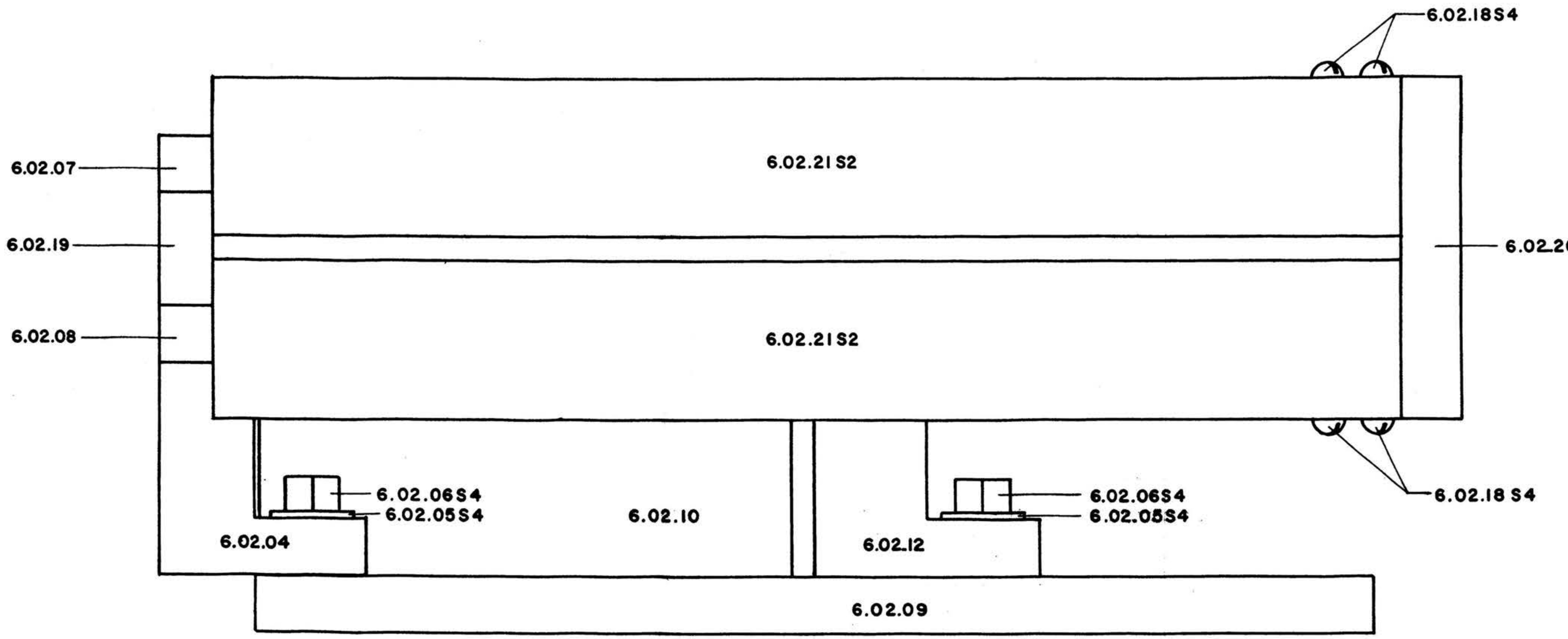
FIGURE 6.02.03 A



— SIDE VIEW —

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	MASK ASSEMBLY
DWG. No. 6.02.00 B	6.02.00

FIGURE 6.02.03B



M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	MASK ASSEMBLY
DWG. No. 6.02.00E	6.02.00

aperture. The form plates are held together by tie blocks 6.02.20 and 6.02.19.

The mask is pivoted on a 0.250 inch pin (6.02.03S1) at the grating normal end so that it will swing away from the film holder. The mask is secured by index pin 6.02.14 when in use. When this pin is removed, the mask is free to swing away giving access to the film holder. In the hinged out position, the outer end of the mask rests on support 6.02.10.

With cap screws 6.02.06S4 loosened, the mask support blocks (6.02.04 & 6.02.12) may be shifted to bring the mask into the desired position relative to the film holder.

The entire mask assembly is mounted on an 0.500 inch aluminum base plate (6.02.09) containing bolt down and alignment pin holes so that the unit may be installed on and removed from the spectrograph mounting plate without destroying its alignment.

6.02.04: Film Positioner (Assembly 6.03.00)

The film positioner supports the film holder and contains all adjustments required to position the holder correctly on the focal circle and to shift the film or plate vertically for multiple exposures. A photograph of the positioner mechanism is shown in figure 6.02.04-A.

The film holder is supported by four pins (6.03.36S4) that are retained by support blocks 6.03.35-2. The film holder longitudinal position may be adjusted by turning adjustment screws 6.03.20-2 on each side of the positioner.

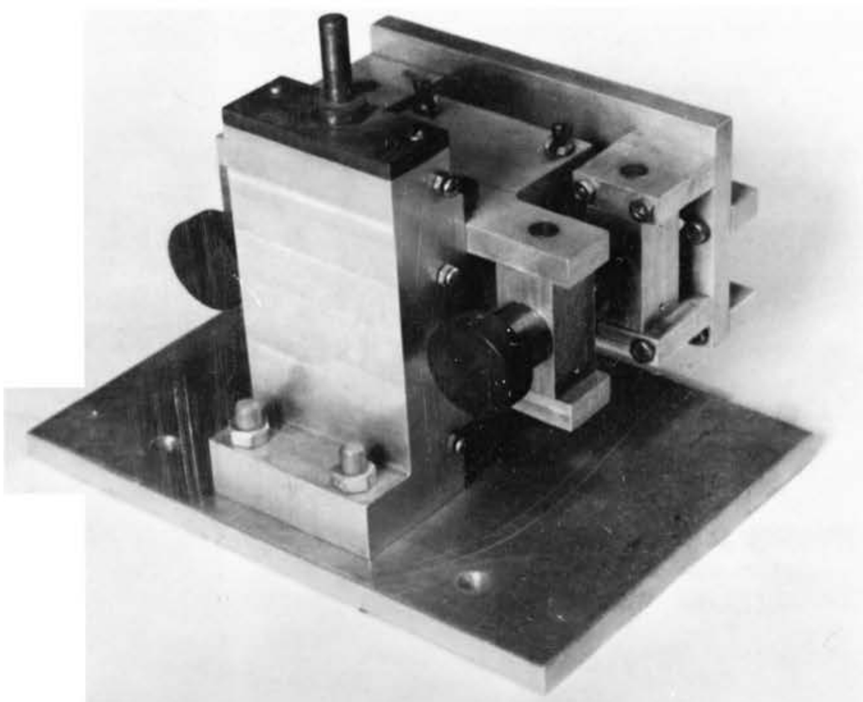


Figure 6.02.04A: Film Positioner

Once the adjustment is completed, it may be locked by tightening wing nuts 6.03.17S2 until the clamp block (6.03.32) is held secure by clamp plates 6.03.13-2.

Vertical motion is provided by a set of ways (6.03.02 & 6.03.03) and a drive screw (6.03.04). The ways are driven from outside the vacuum system by the film drive linkage (6.04.00).

The entire film positioner mechanism is assembled on a base plate having provision for mounting and pinning the assembly to the instrument mounting plate. The assembly may be removed and re-installed without loss of alignment.

6.02.05: Film Drive Linkage (Assembly 6.04.00)

The film positioner vertical drive power is transmitted mechanically from outside the vacuum chamber through a vacuum seal in flange assembly 6.04.07. Because the top flange could not be located directly over the drive screw, a double elbow drive consisting of two sets of miter gears (6.04.02S4) held in two right angle brackets (6.04.01-2) and a 3/8 inch shaft (6.04.04) was designed. The shaft is hand driven via crank 6.04.06 extending through the vacuum seal at S.L. 56.625 in flange assembly 6.04.07. A drawing of the drive linkage is shown in figure 6.02.05-A (Assembly drawing 6.04.00-B).

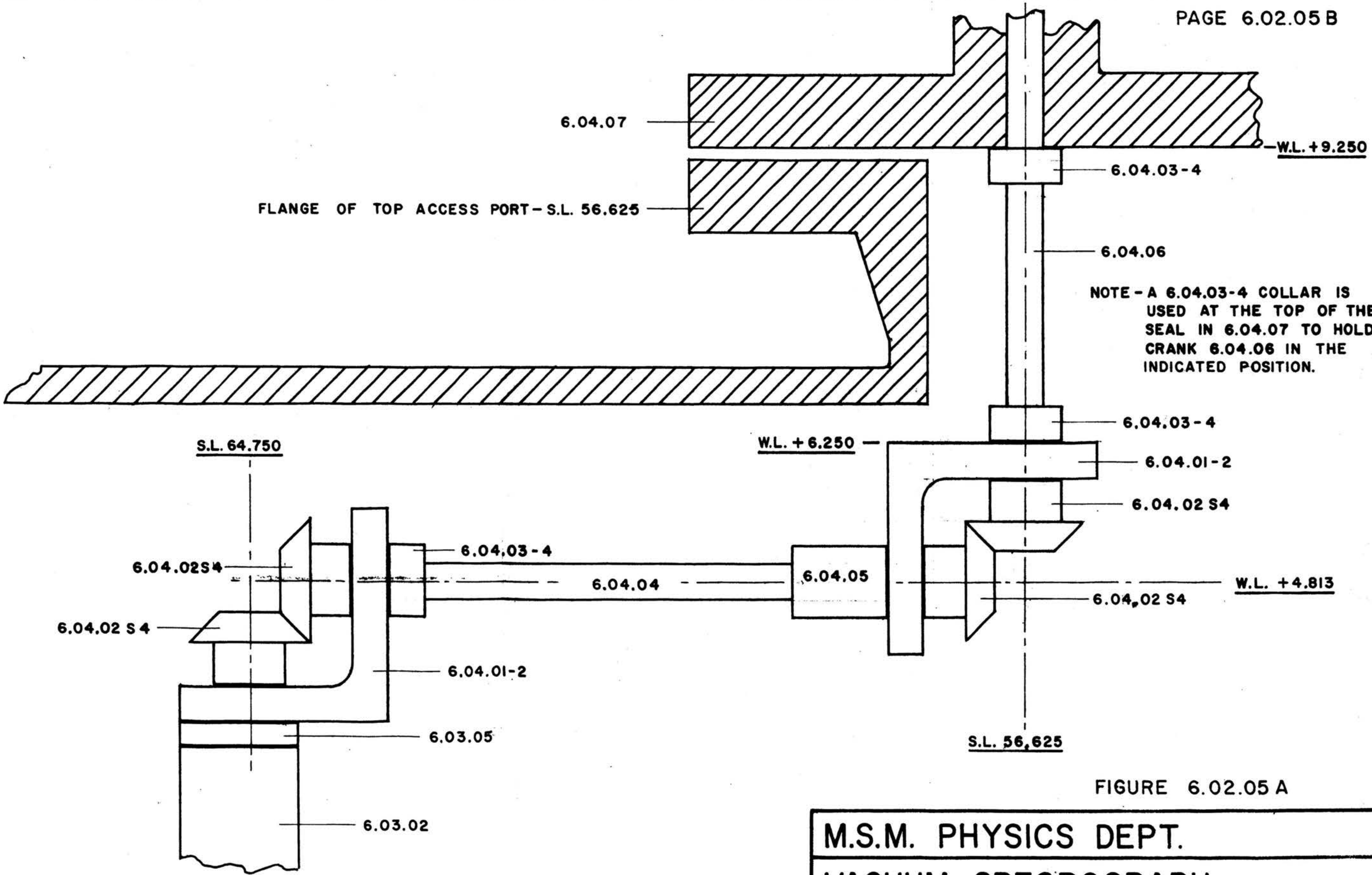


FIGURE 6.02.05 A

M.S.M. PHYSICS DEPT.	
VACUUM SPECROGRAPH	
	FILM DRIVE LINKAGE
DRAWING No. 6.04.00-B	ASSEMLY 6.04.00

6.03.00: Installation

6.03.01: Film Positioner Installation

The film positioner assembly is mounted on mounting plate 7.04.01 between station lines 60.000 and 67.000 with the film holder facing the grating end of the instrument. With the base plate (6.03.01) edges parallel with the edges of mounting plate 7.04.01, the base plate is secured by four cap screws (6.03.16S4) at station lines 66.000 and 62.000. After the unit is securely attached to the mounting plate, two 0.250 inch alignment holes are drilled through the 0.250 inch "A" holes in mounting plate 7.04.01 at (66.000, 4.500) and 66.000, -4.500). (The mounting plate is removed from the instrument during this operation.) Alignment pins 6.03.07 are installed in these holes.

6.03.02: Film Holder Loading and Installation

The film holder is designed to be installed via the vacuum chamber side access port at station line 54.625. If the mask assembly (6.02.00) is in place, it is necessary to swing the mask away from its operating position. This is done by pulling alignment pin 6.02.14 and swinging the nearest end of the mask toward the grating. The film holder is then inserted through the port and hooked to the positioner assembly by dropping it down on the four pointed pins (6.03.36S4) extending upward from support blocks 6.03.35-2. Four 0.250 inch holes are located so as to mate with these pins.

Strips of 35 mm roll film 11.6 inches long are inserted in the holder in the following manner. One end of the film is pressed down on the three spikes in the face plate (6.01.02) and the film is laid with the emulsion side toward the face plate. The film backing band (6.01.05) is hooked on the end of the face plate and pulled down over the film strip. The backing band clamp block (6.01.06) is then hooked on the opposite end of the face plate and thumbscrew 6.01.07 is tightened until the spring brass backing band holds the film strip edges in contact with the face plate.

The glass spectroscopic plates,10 x 1.25 inches, are loaded in the same manner except care must be exercised in order to place the end of the plate so that it is not in contact with the film retainer spikes in one end of the face plate.

6.03.03: Mask Installation

The mask assembly is bolted to mounting plate 7.04.01 between station lines 57.000 and 49.500 with three cap screws (6.02.06S7). After the assembly is secured, two 0.250 inch alignment pin holes are drilled in the base plate (6.02.09) through the corresponding holes in the mounting plate at (54.000, -4.500) and (50.000, 4.500). Alignment pins 6.02.14-3 are then installed from the top side. The mounting plate must be removed for the drilling of the alignment holes.

6.03.04: Drive Linkage Installation

The film drive linkage is installed in accordance with figure 6.02.05-A (Assembly Drawing 6.04.00). Installation of this assembly must be made after the film positioner is in place. Once installed, it may be disconnected at coupling 6.04.05S1 by loosening the coupling set screws holding shaft 6.04.04S1. This feature allows removal of the rear portion of the linkage with the film positioner mechanism. Shaft collar 6.03.06 must be removed to allow installation of bracket 6.04.01-2 and miter gear 6.04.02S4 at the top of the positioner mechanism.

6.04.00: Adjustment

6.04.01: Film Positioner Adjustment

Adjustment of the film positioner to place the film holder on the focal circle is made by adjustment screws 6.03.20-2 with wing nuts 6.03.17S2 loose enough to allow the clamp block (6.03.32) to slide between plates 6.03.13-2. With the mask swung away from the film holder and the reference arm in place (see section 7.), the adjustment screws are turned until the film side of the face plate is coincident with the end of the reference arm along the entire face of the film holder. The adjustment is then locked by tightening wing nuts 6.03.17S2. This completes the rough adjustment. Fine adjustments, if necessary, must be made by photographic methods.

6.04.02: Mask Adjustment

After final adjustment of the film holder to the focal circle is complete, the mask is placed so that it is 0.031 inch in front of the film holder. The adjustment is then locked by tightening cap screws 6.02.06S4.

6.05.00: Construction

All detailed information required for part fabrication and assembly of the film holder, film positioner, film drive linkage and mask is given by the series 6.00.00 drawings at the end of this section. Some of the assembly drawings are used as illustrations in the text of this thesis. These drawings are

	6.00.00-B, C & E	(see figures 6.02.01-A, B & C.),
	6.02.00-B & E	(see figures 6.02.03-A & B.)
and	6.04.00-B	(see figure 6.02.05-A.).

Drawing 6.00.00-A

Sheet 1 of 1

Film Positioner, Holder & Mask
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y No:	Dwg. No:	Note:	Description:
6.00.00	6.00.00-A 6.00.00-B 6.00.00-C 6.00.00-E		Film Positioner Film Holder and Mask Assemblies
6.01.00	6.01.00-A		Film Holder
6.02.00	6.02.00-A		Mask Assembly
6.03.00	6.03.00-A		Film Positioner
6.04.00	6.04.00-A		Film Drive Linkage

Drawing 6.01.00-A
Film Holder
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
6.01.00	6.01.00-A 6.00.00-B 6.00.00-C 6.00.00-E	A	Film Holder Ass'y View Ass'y View Ass'y View
6.01.01	6.01.01 6.01.11		Upper Form Plate
6.01.02	6.01.02	B	Face Plate
6.01.03	6.01.03		Spacer Block
6.01.04	6.01.04		Tie Block
6.01.05	6.01.05		Film Backing Band
6.01.06	6.01.06		Backing Band Clamp Block
6.01.07	6.01.07		Backing Band Thumb-screw
6.01.08S1	None		Screw 2-3/4", 10-24, Round Head, Brass
6.01.09S4	None		Screw, 1-1/4", 10-24, Flat Head, Brass
6.01.10S5	None		Hex Nut, 10-24, Brass
6.01.11	6.01.01 6.01.11		Lower Form Plate
6.01.12S22	None		Screw, Flat Head, 3/8", 6-32, Brass
6.01.13S4	None		Pin, 1", 1/8" dia., Dowel, Steel

ASSEMBLY NOTES:

(A)

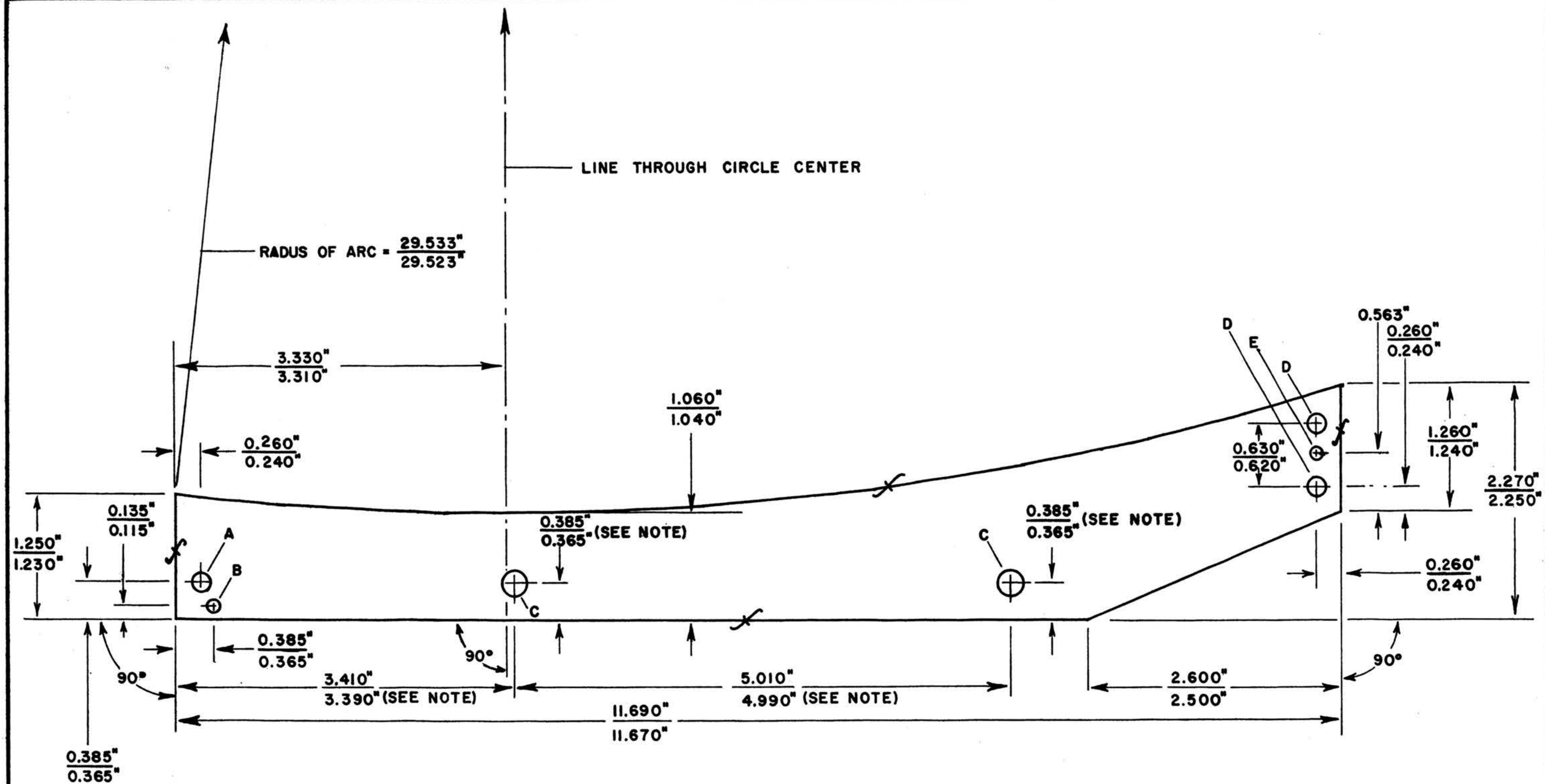
Assemble the film holder in accordance with assembly drawings 6.00.00-B, C and E. Unit must be assembled so that edges of form plates 6.01.01 and 6.01.11 are in the same planes.

After assembly of the two form plates with spacer block 6.01.03 and tie block 6.01.04, pin the form plates to the end blocks using pins 6.01.13S4 in the 1/8 inch holes designated by "B" and "E" in dwg. 6.01.01-6.01.11.

After assembly of the film holder is completed, it is placed on the film positioner mechanism as shown in drawings 6.00.00-B, C and E and clamped in place for the drilling of the "C" holes in parts 6.01.01 and 6.01.11 and the holes for pins 6.03.36S4 in the film holder support blocks (6.03.35). All four holes must be drilled in assembly so that they will match. These holes must be parallel. After drilling the holes in assembly with an 0.250" drill, the film holder is removed and the holes in the form plates are reamed to 0.255" to provide a sliding fit over the support pins (6.03.36S4).

(B)

The face plate (6.01.02) is clamped in place against the circle segment formed by assembled form plates 6.01.01 and 6.01.11 so that it is in continuous contact with the arc milled in the edge of the form plates. Starting at a point 0.4" from one end, holes are drilled, tapped and countersunk every one inch along lines 0.250" from the upper and lower edges of the face plate. Screws 6.01.12S22 are installed to hold the face plate against the form plates. Care must be exercised so as not to kink the face plate.



GUIDE TO HOLES

A – No. 11 DRILL. HOLES IN 6.01.01 & 6.01.11 CONCENTRIC WITHIN 0.005" WHEN CURVED SURFACES COINCIDE.

B – 1/8".

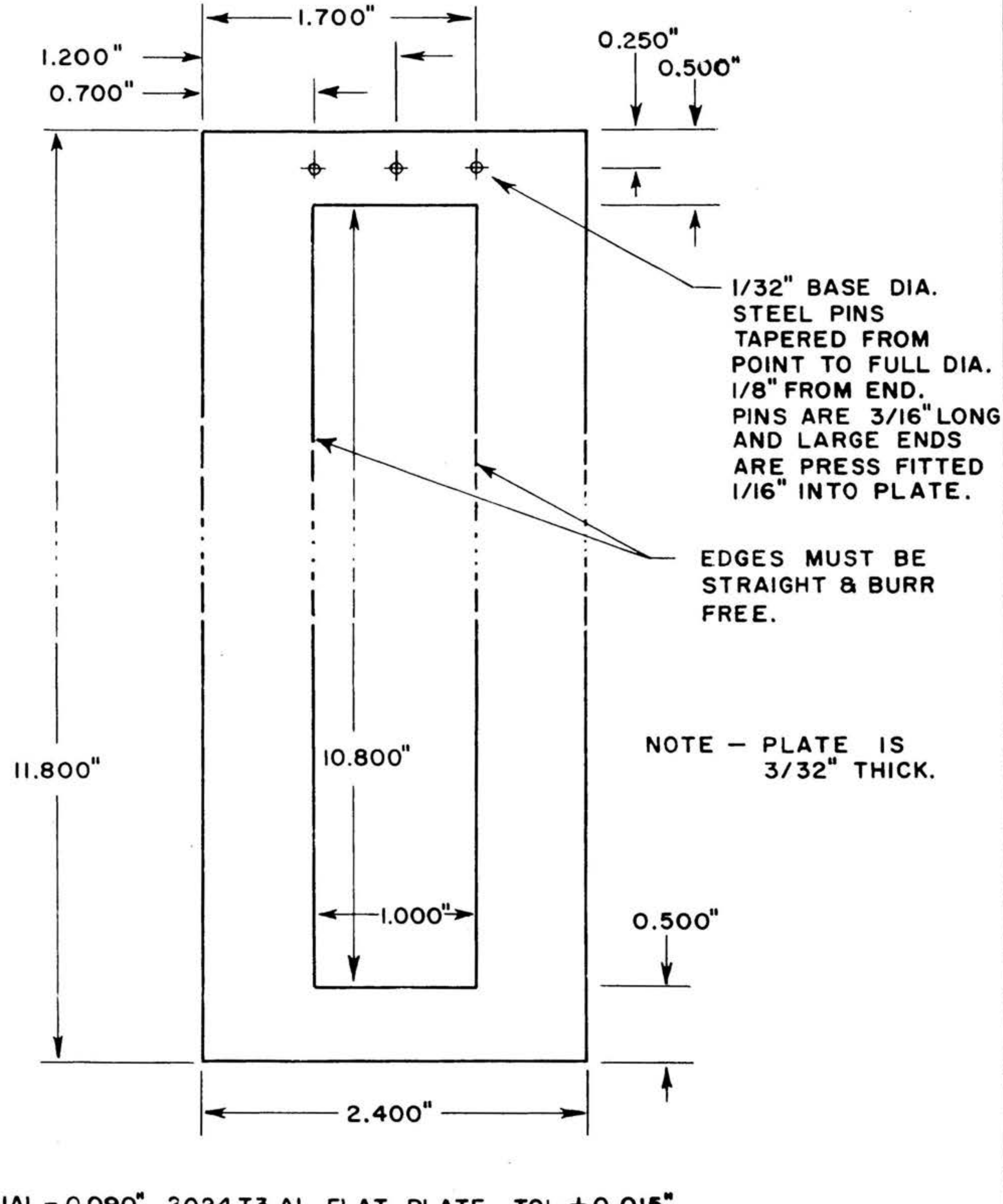
C – 0.255" DRILL IN ASSEMBLY. SEE TEXT.

D – No. 11 DRILL. COUNTERSINK FOR 10-24 SCREW.– BOTTOM SIDE OF 6.01.01.
– TOP SIDE OF 6.01.11.

E – 1/8". DRILL IN ASSEMBLY.

MATERIAL – 0.500" JIG AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
UPPER FORM PLATE	LOWER FORM PLATE
6.01.01	6.01.11

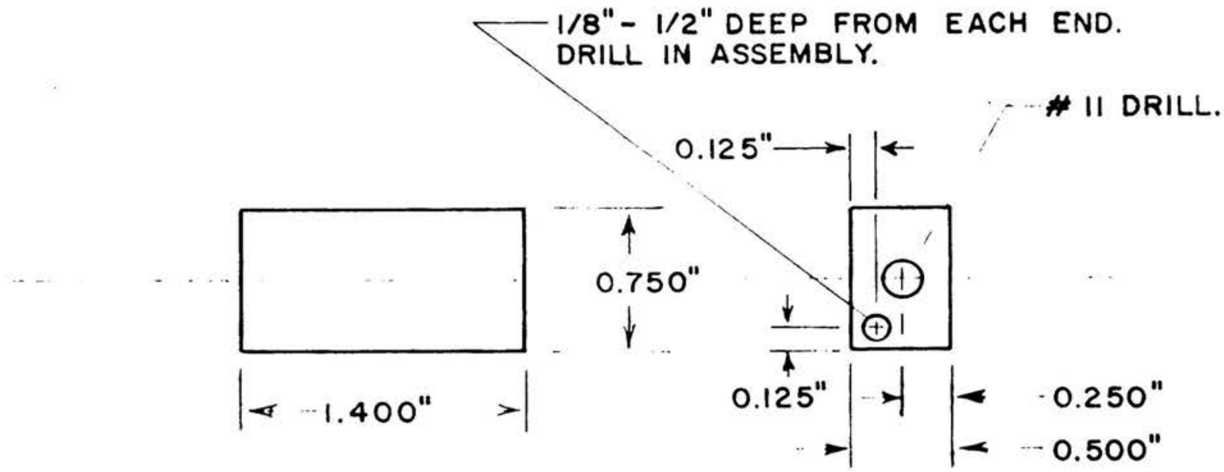


MATERIAL – 0.090" 2024 T3 AL. FLAT PLATE. TOL – ± 0.015"

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

	FACE PLATE
	6.01.02



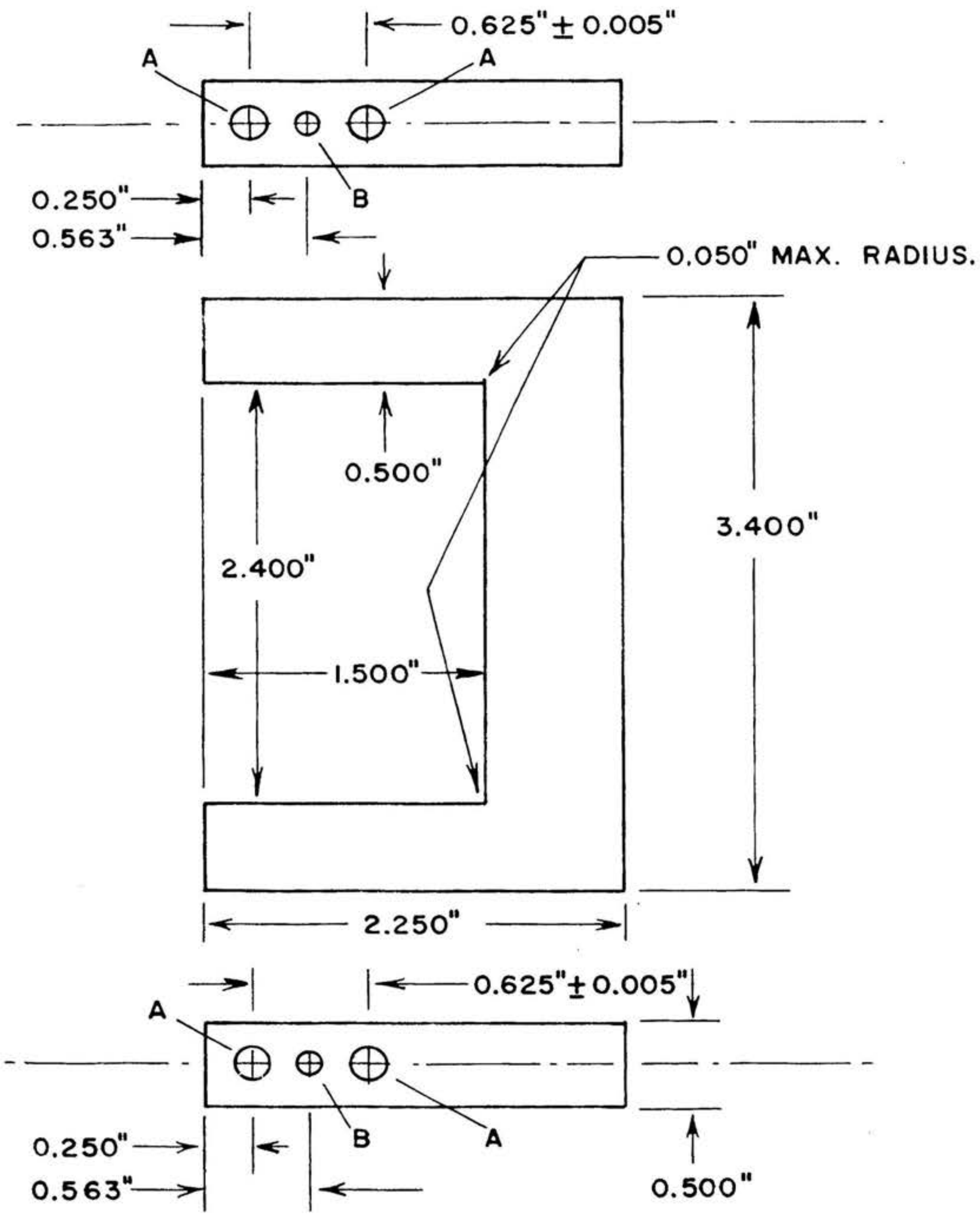
TOL - ±0.015", ANGULAR - ± 0.25°

MATERIAL - 24 ST AL.

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

	SPACER BLOCK
	6.01.03

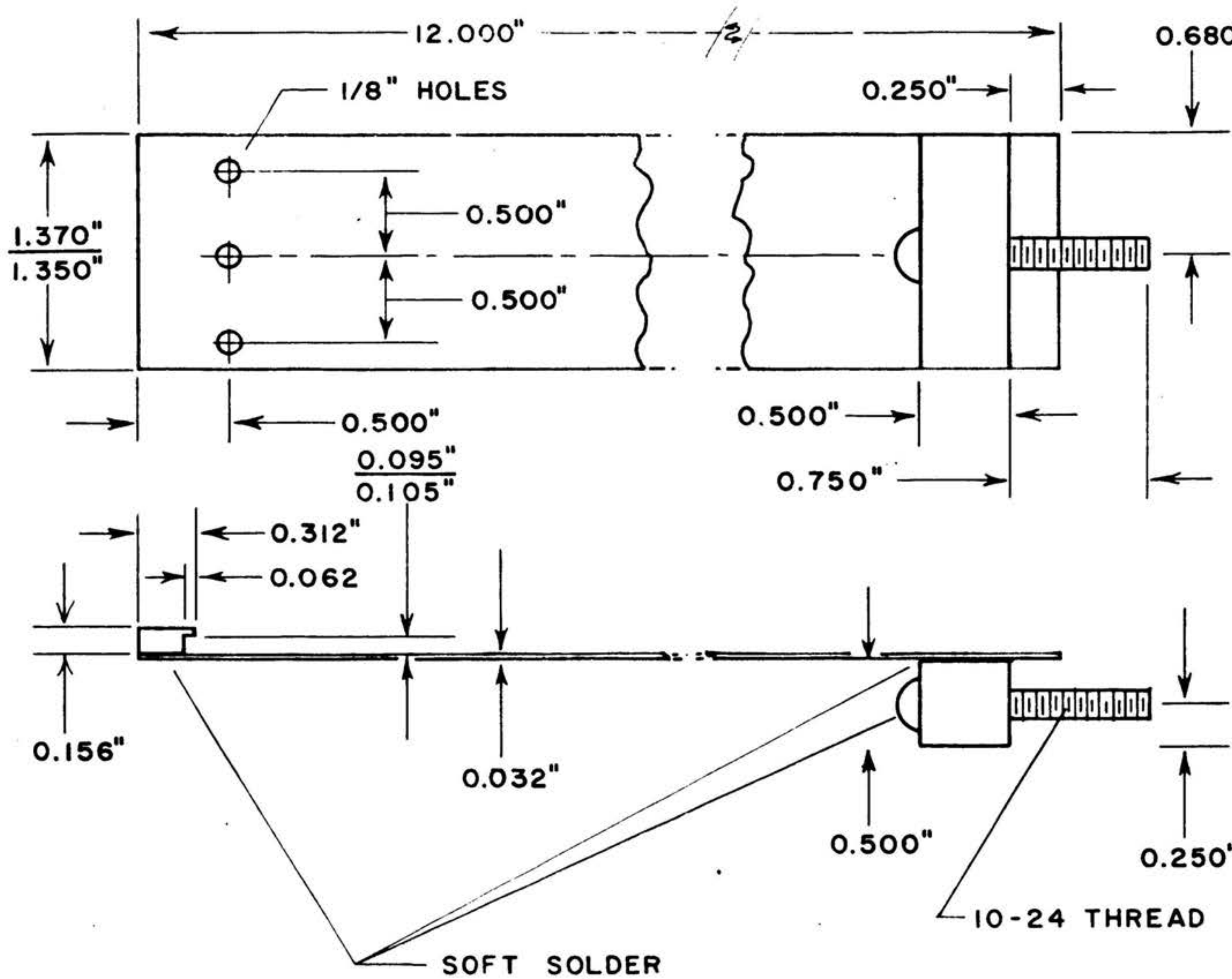


A - No. 11 DRILL. HOLES MUST BE CONCENTRIC WITHIN 0.005".
B - 1/8".

TOL - ±0.015"

MATERIAL - 24 ST AL.

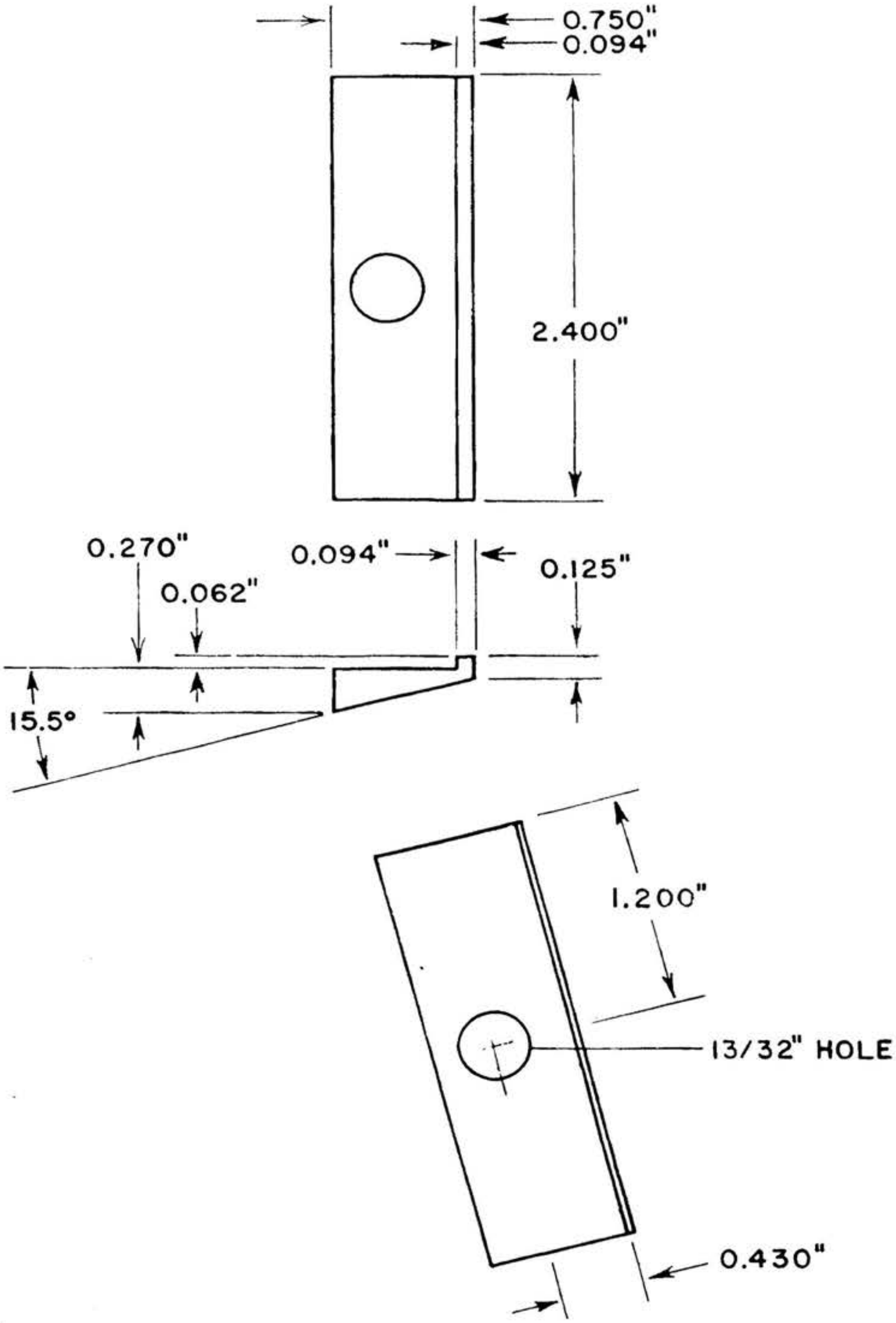
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	TIE BLOCK
	6.01.04



TOL - ±0.015" EXCEPT AS INDICATED.

MATERIAL - YELLOW BRASS, 1.250" 10-24 BRASS MACHINE SCREW & 0.032" YELLOW BRASS FLAT STRIP - SPRING TEMPER.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	FILM BACKING BAND
	6.01.05



MATERIAL - BRASS

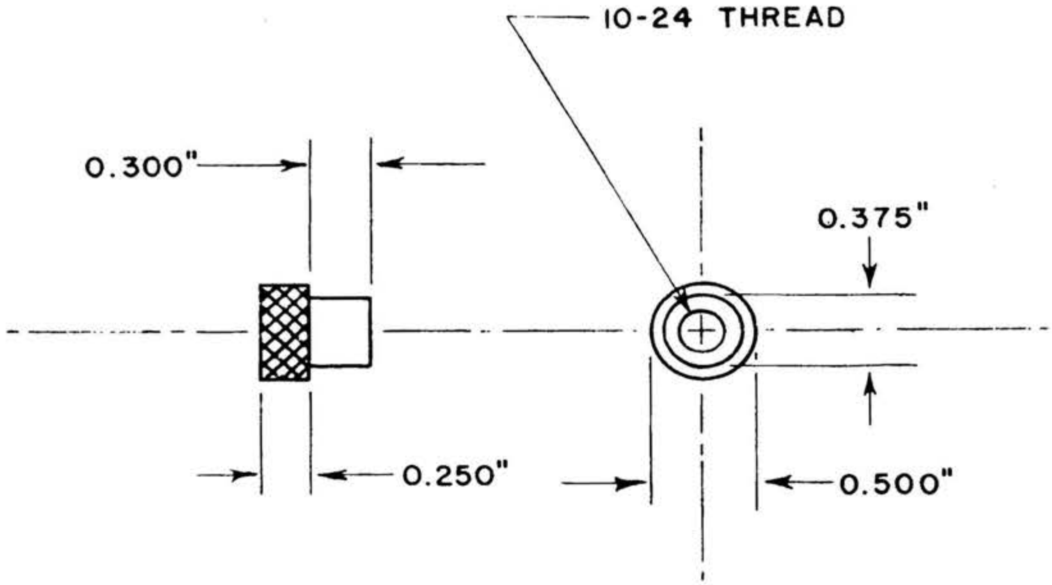
TOL- ± 0.010"

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

BACKING BAND CLAMP BLOCK

6.01.06



MATERIAL - BRASS

TOL - ± 0.015"

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	BACKING BAND THUMBSCREW
	6.01.07

Drawing 6.02.00-A
Mask Assembly
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
6.02.00	6.02.00-A 6.02.00-B 6.02.00-E 6.00.00-C	A	Mask Ass'y Ass'y View Ass'y View Ass'y View
6.02.01S4	None		Screw, 7/8", 10-24, Flat Head, Brass
6.02.02S1	None		Pin, 2", 1/8" dia., Steel
6.02.03S1	None		Pin, 3.9", 1/4" dia., Steel
6.02.04	6.02.04		End Support Block
6.02.05S4	None		Washer, Flat, 7/16" I.D., Brass
6.02.06S7	None		Screw, Cap, 1", 3/8" dia., Brass
6.02.07	6.02.07 6.02.08	B	Mask Upper Form Plate
6.02.08	6.02.07 6.02.08	B	Mask Lower Form Plate
6.02.09	6.02.09		Base Plate
6.02.10	6.02.10		Support Block
6.02.11S2	None		Screw, 1-1/2", 10-24, Flat Head, Brass
6.02.12	6.02.12		Center Support Block

Part No:	Dwg. No:	Note:	Description:
6.02.13	6.02.13	C	Index Pin Plate
6.02.14-3	6.02.14-3		Index Pin
6.02-15S2	None		Screw, 1", 10-24, Flat Head, Brass
6.02.16S4	None		Pin, 1", 1/8" dia., Steel
6.02.17S24	None		Screw, 3/8", 6-32, Flat Head, Brass
6.02.18S4	None		Screw, 1", 10-24, Round Head, Brass
6.02.19	6.02.19		Mask Spacer Block
6.02.20	6.02.20		Mask End Tie Block
6.02.21S2	None		Mask Plate, 11 x 1.4" Strip of 0.063" 2024 Al. Plate. Edges Must be Straight & Smooth

ASSEMBLY NOTES:

(A)

Assemble mask in accordance with drawings 6.02.00-B, 6.02.00-E and 6.00.00-C. The mask must be assembled so that the curved edges of the form plates are coincident.

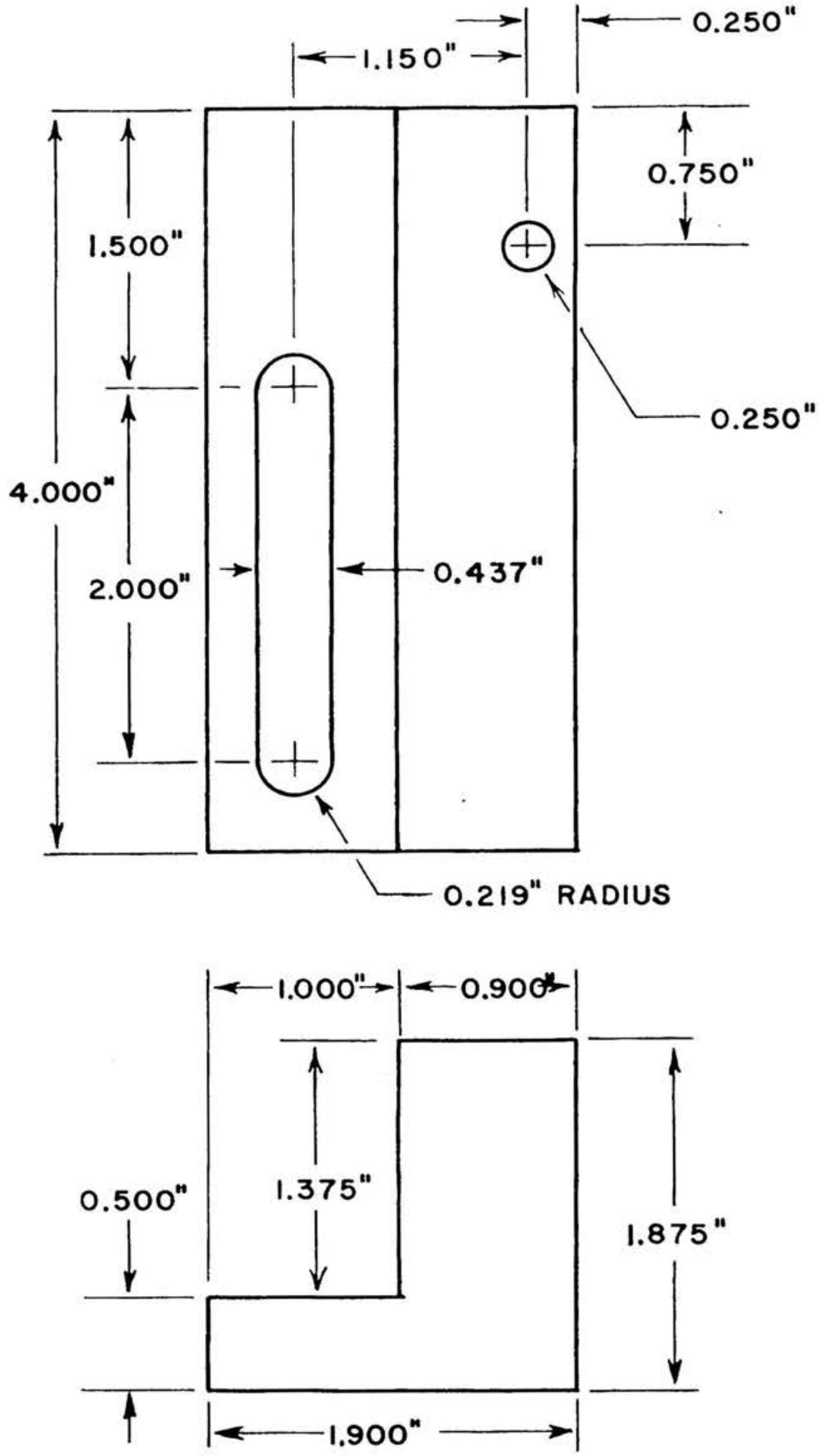
After assembly of the form plates (6.02.07 and 6.02.08) with spacer block 6.02.19 and tie block 6.02.20, pin the parts together with pins 6.02.02S1 and 6.02.16S4.

(B)

After assembly of the form plates and tie blocks, clamp mask plates 6.02.21S2 in place against the curved form plates as shown in dwgs. 6.02.00-B, 6.02.00-E and 6.00.00-C so that they are in continuous contact with the form plates along the curved surfaces. Holes are drilled, tapped and countersunk for screws 6.02.17S24 along the mask surface so that they are in the center of the form plate edges. The screws are spaced one inch apart except at the ends where the end screws are placed 0.2" from the mask plate ends. The next screws are placed 1" from the ends.

(C)

Index pin plate 6.02.13 is attached and pinned to the lower form plate as shown in dwgs. 6.00.00-C, 6.02.00-B and 6.02.00-E with screws 6.02.15S2 and two 6.02-.6S4 pins.



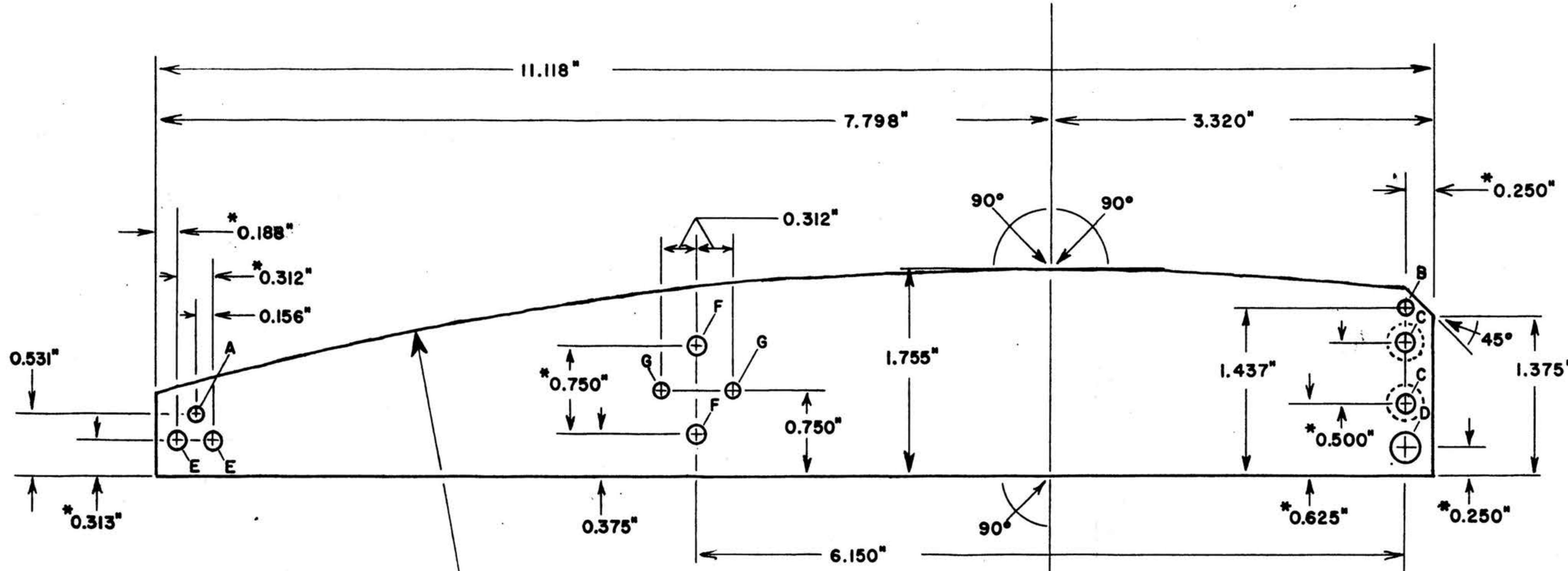
TOL — ± 0.015"

MAT. — 75 ST AL.

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

JKH	END SUPPORT BLOCK
	6.02.04

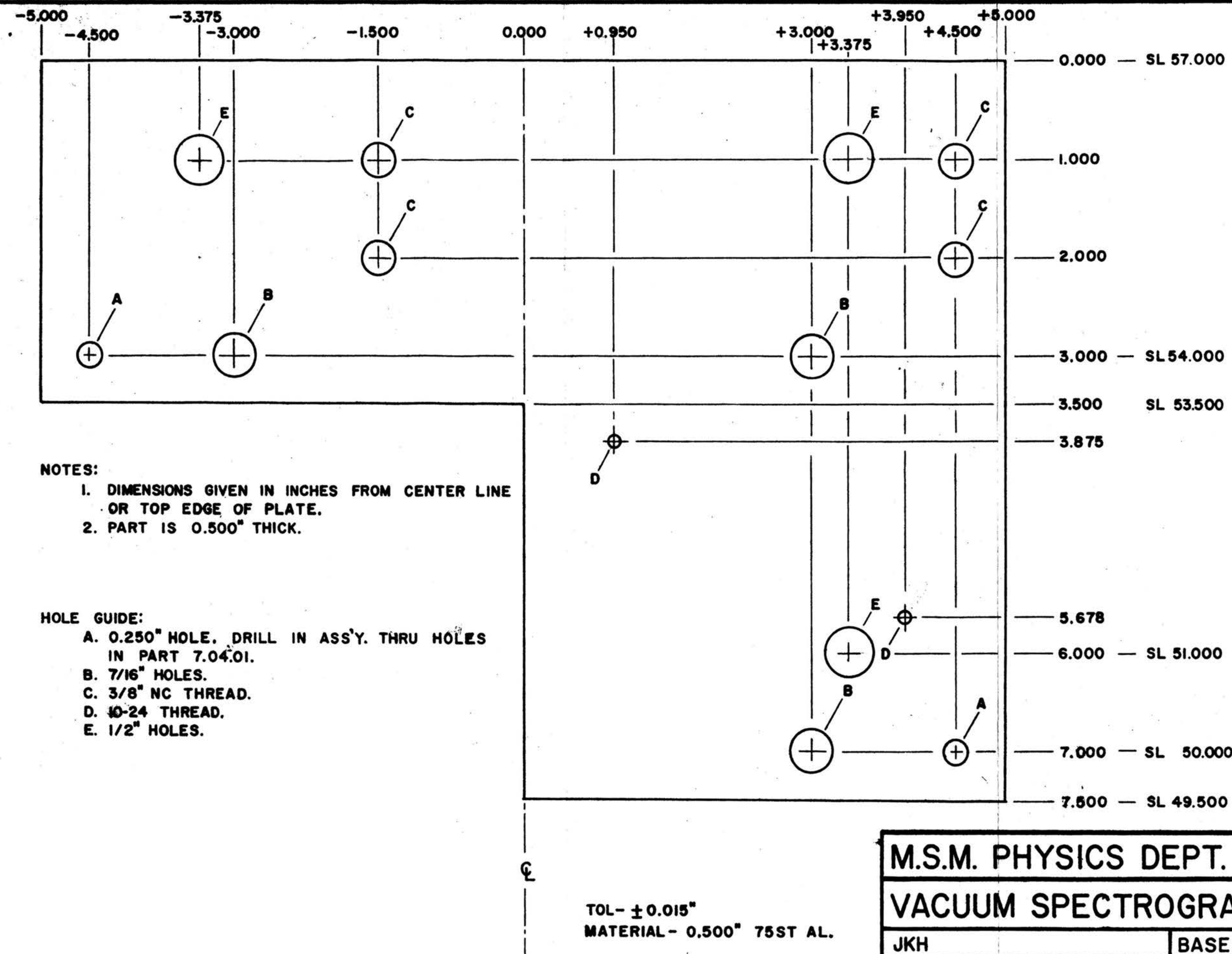


GUIDE TO HOLES:

A 1/8" HOLE. DRILL IN ASS'Y.
B 1/8" HOLE. DRILL IN ASS'Y.
C # 11 DRILL HOLE. COUNTERSINK - TOP SIDE OF PART 6.02.07 - BOTTOM SIDE OF PART 6.02.08.
D 0.250" - DRILL WITH 6.02.07 & 6.02.08 CLAMPED TOGETHER WITH CURVED SURFACES COINCIDENT.
E 10-24 TAP.
F 10-24 TAP. — PART 6.02.08 ONLY.
G 1/8" HOLE. DRILL IN ASS'Y. — PART 6.02.08 ONLY.

*TOL- ±0.015" EXCEPT ±0.005" WHERE INDICATED BY (*).
MATERIAL- 0.500" AL. JIG PLATE.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
MASK UPPER FORM PLATE	MASK LOWER FORM PLATE
6.02.07	6.02.08



NOTES:

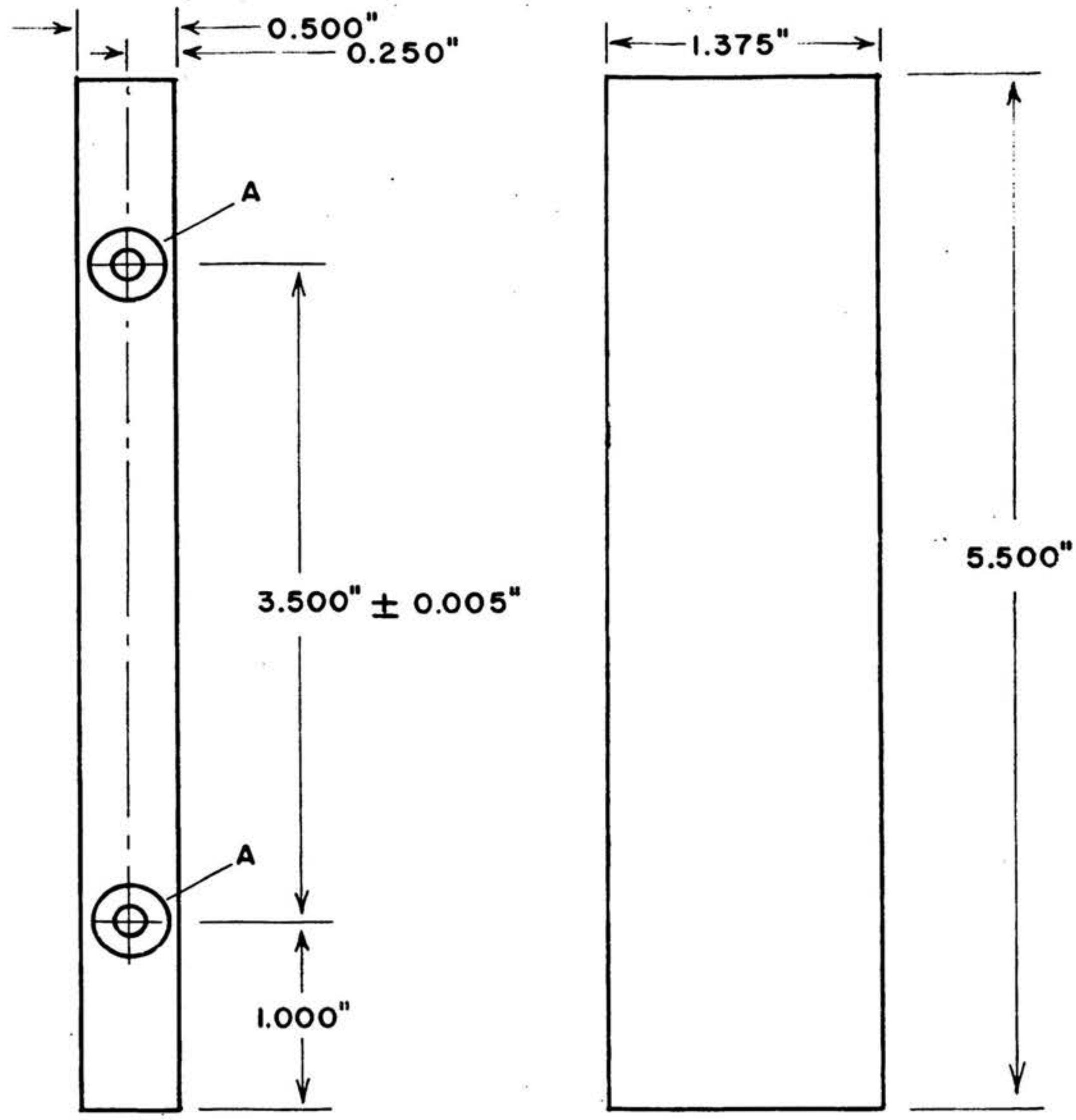
1. DIMENSIONS GIVEN IN INCHES FROM CENTER LINE OR TOP EDGE OF PLATE.
2. PART IS 0.500" THICK.

HOLE GUIDE:

A. 0.250" HOLE. DRILL IN ASS'Y. THRU HOLES IN PART 7.04.01.
B. 7/16" HOLES.
C. 3/8" NC THREAD.
D. 10-24 THREAD.
E. 1/2" HOLES.

TOL- ± 0.015"
MATERIAL- 0.500" 75ST AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH	BASE PLATE
	6.02.09



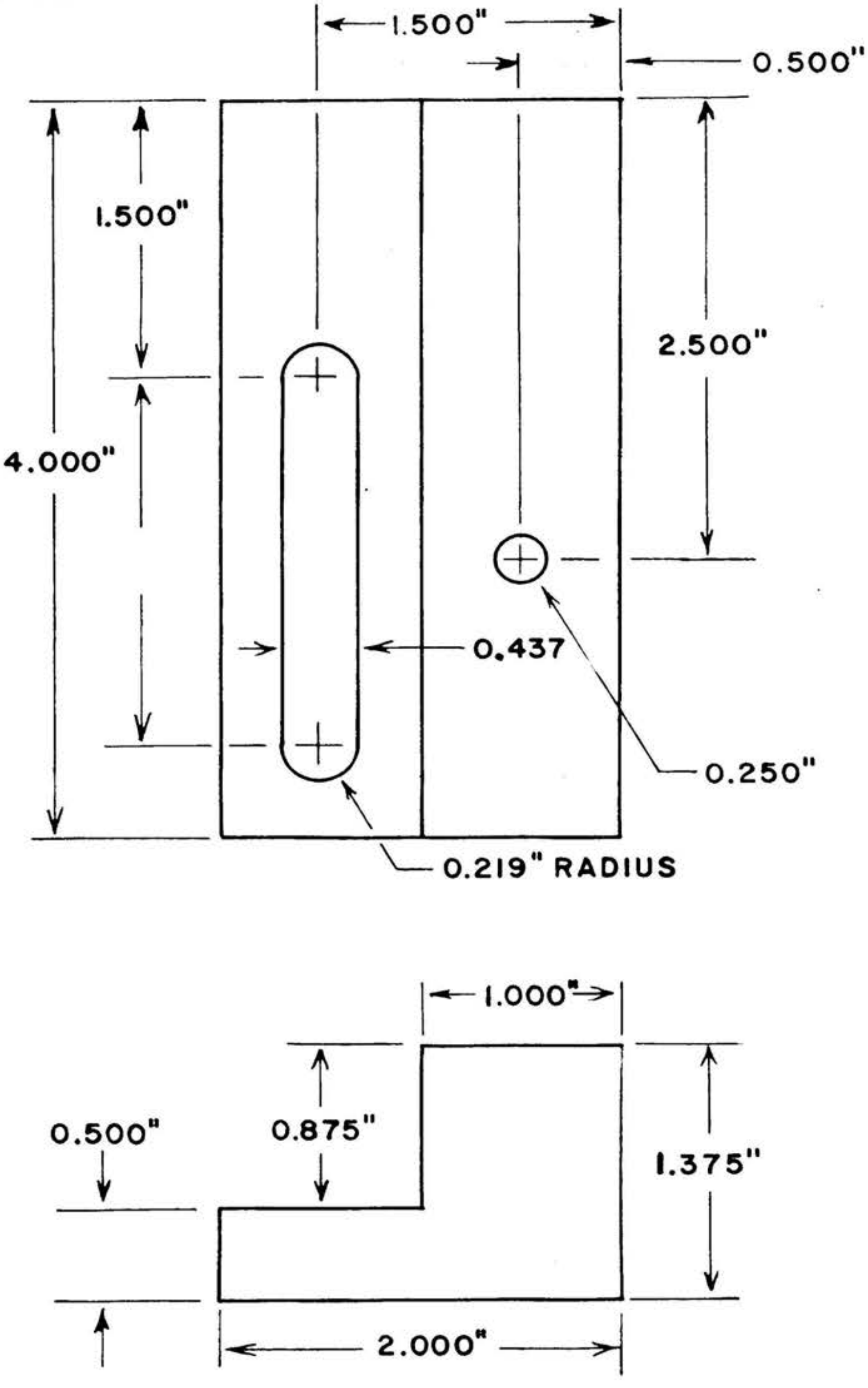
GUIDE TO HOLES

A - No. 10 DRILL. - COUNTERBORE 5/16" WITH 3/8" DRILL.

TOL - ± 0.015"

MATERIAL 75 ST AL.

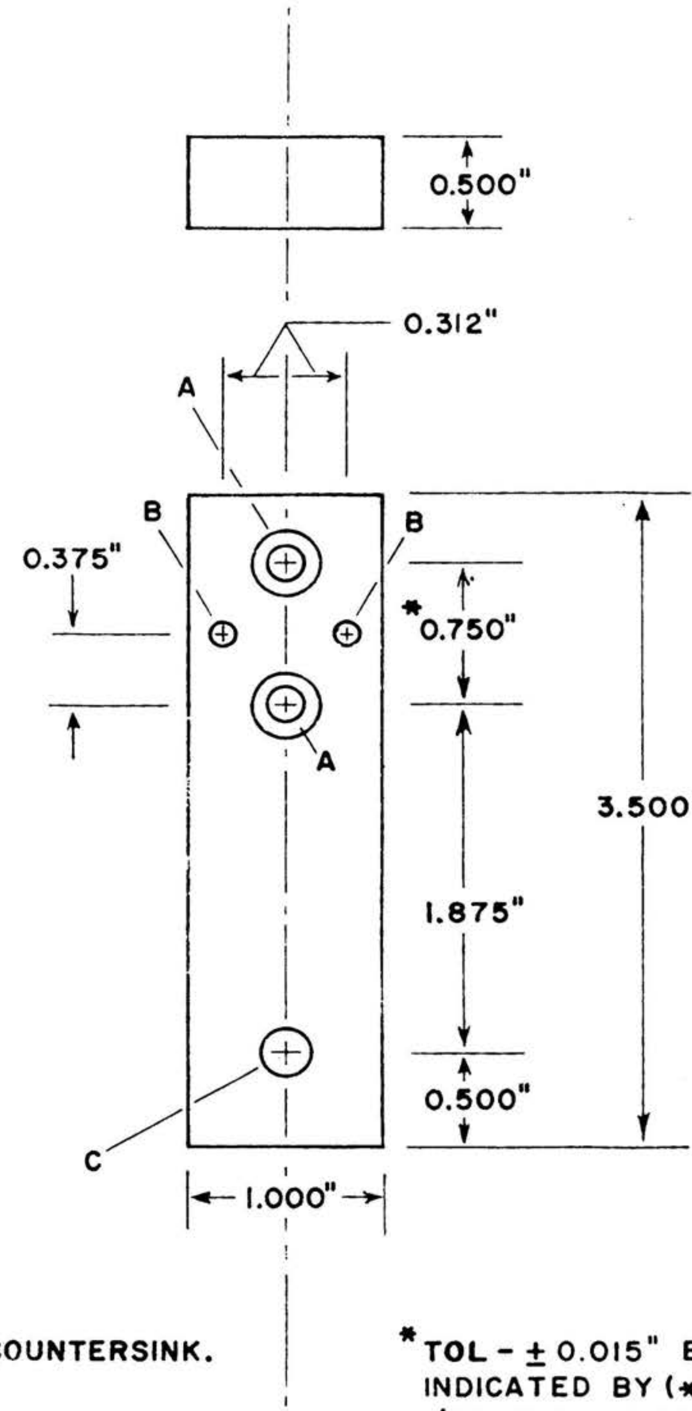
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	SUPPORT BLOCK
	6.02.10



TOL – ± 0.015"

MATERIAL – 75 ST AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH	CENTER SUPPORT BLOCK
	6.02.12



GUIDE TO HOLES

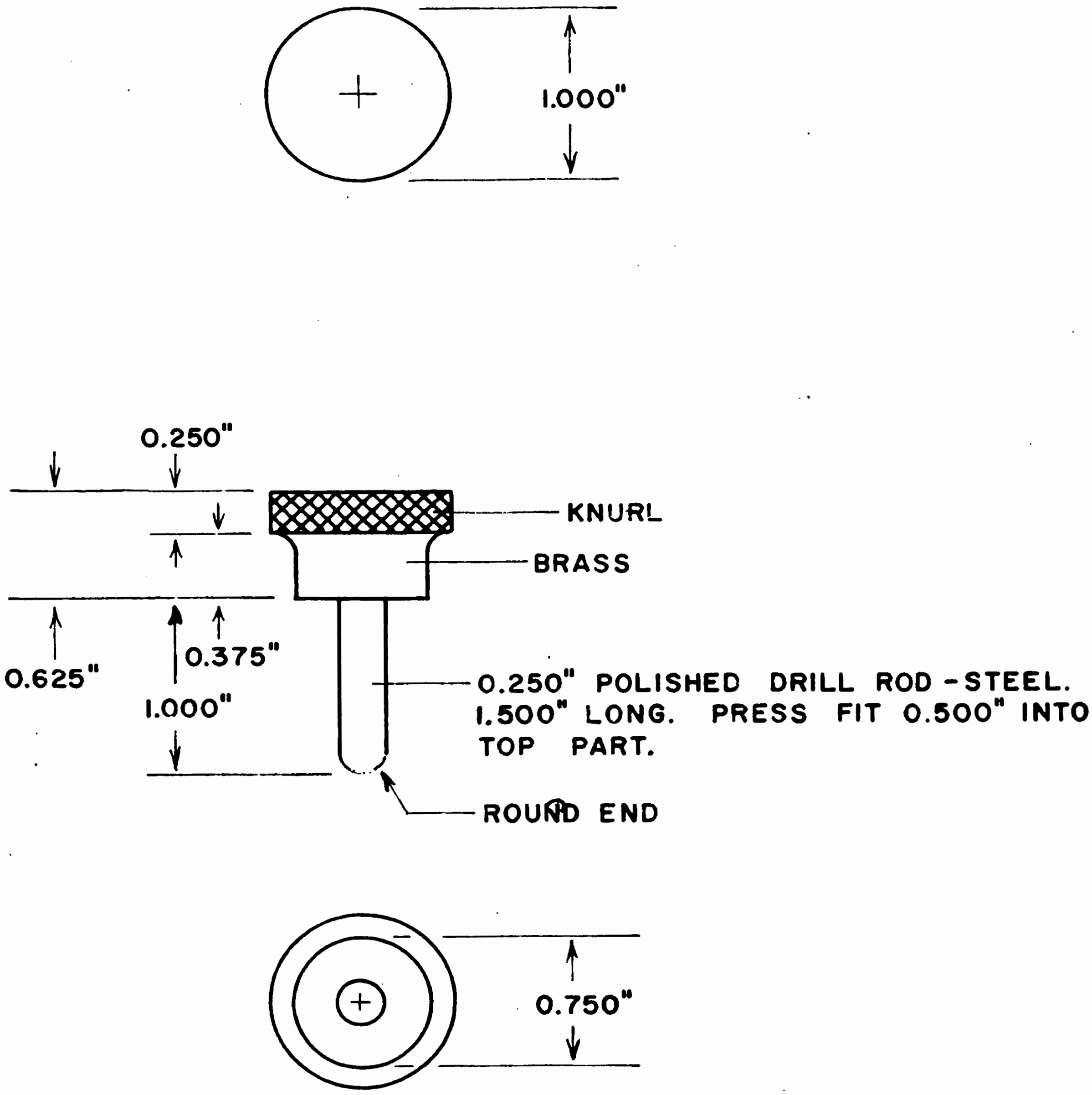
A – No. 11 DRILL. COUNTERSINK.
B – 1/8" DRILL.
C – 0.253" HOLE.

*TOL – ± 0.015" EXCEPT WHERE INDICATED BY (*) ± 0.005."
MATERIAL – 0.500" AL. JIG PLATE.

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

	INDEX PIN PLATE
	6.02.13



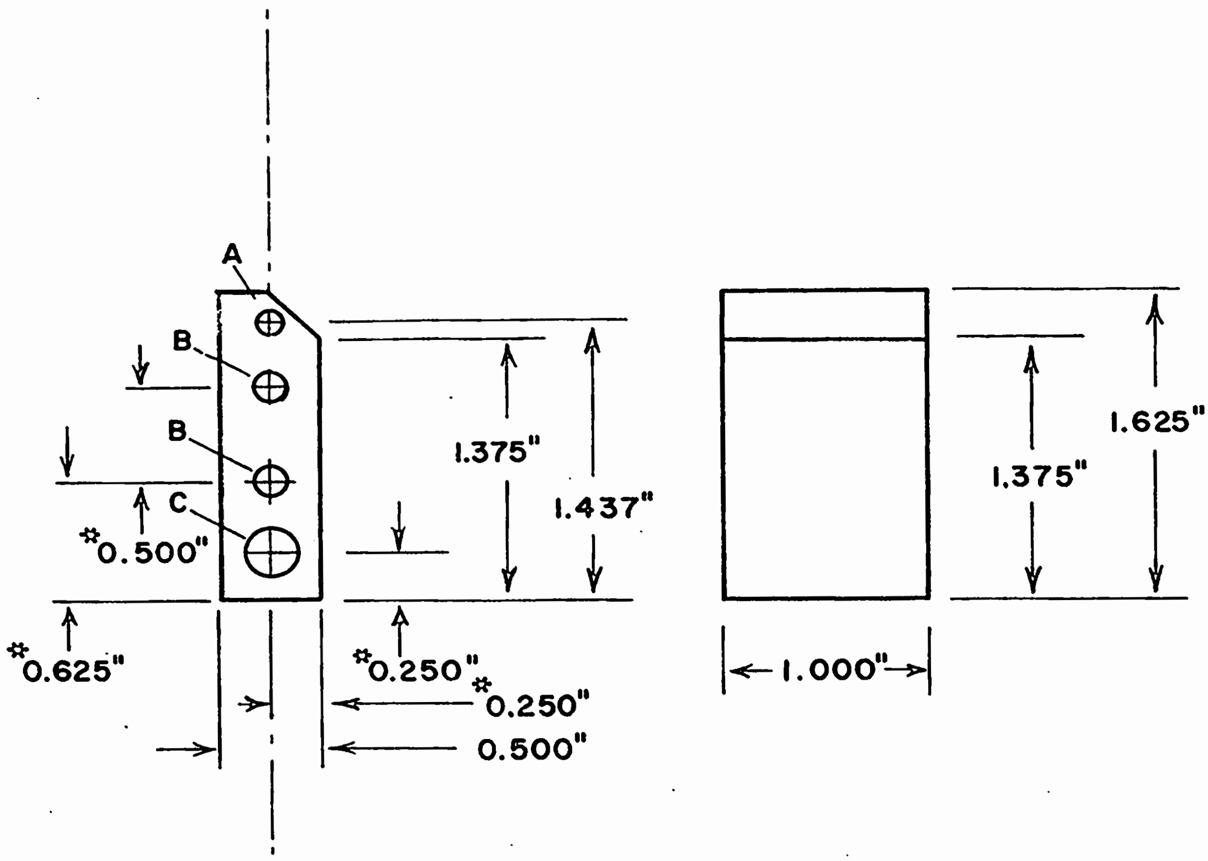
TOL - ± 0.030"

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

INDEX PIN

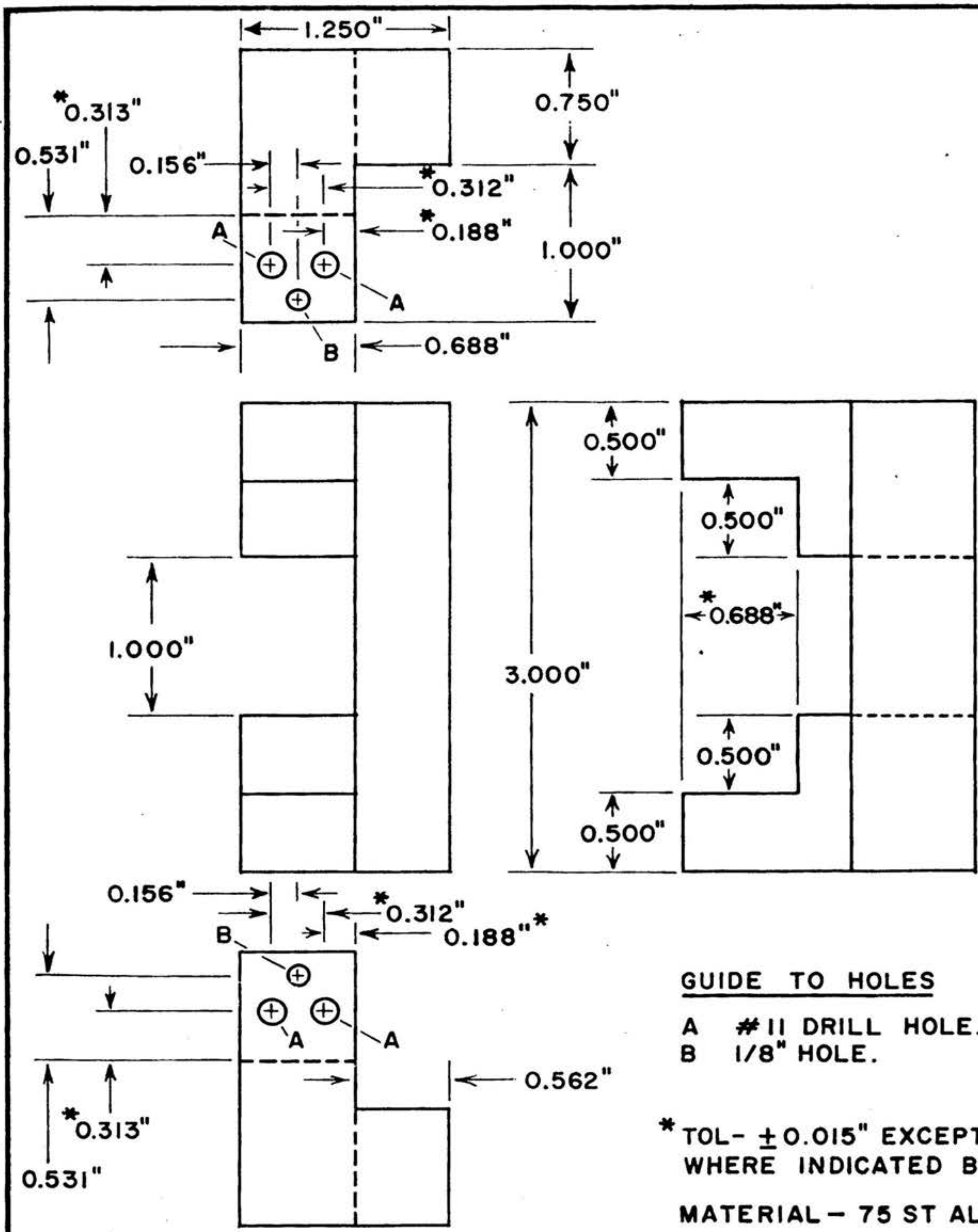
6.02.14



GUIDE TO HOLES
A - 1/8". DRILL 1/2" DEEP FROM EACH END IN ASSEMBLY.
B - 10-24 THREADS. TAP TO 1/2" DEPTH FROM EACH END.
C - 0.250".

*TOL. ± 0.015" EXCEPT 0.005" WHERE INDICATED BY (*).
MATERIAL - 75 ST AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	MASK SPACE BLOCK
	6.02.19



GUIDE TO HOLES

A #11 DRILL HOLE.
B 1/8" HOLE.

* TOL- ±0.015" EXCEPT ±0.005" WHERE INDICATED BY (*).

MATERIAL — 75 ST AL.

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

	MASK, END TIE BLOCK
	6.02.20

Drawing 6.03.00-A
Film Positioner
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
6.03.00	6.03.00-A 6.00.00-B 6.00.00-C 6.00.00-E	A	Film Positioner Ass'y View Ass'y View Ass'y View
6.03.01	6.03.01		Base Plate
6.03.02	6.03.02		Film Lift Ways - Stationary
6.03.03	6.03.03		Film Lift Way Block
6.03.04	6.03.04 6.03.06		Drive Screw
6.03.05	6.03.05 6.03.32		Drive Screw Retainer
6.03.06	6.03.04 6.03.06		Drive Screw Collar
6.03.07-2	6.02.14		Alignment Pin (Same as 6.02.14)
6.03.08S2	None		Screw, 2", 3/8 dia., Flat Head, Steel, N.F. Thread
6.03.09S6	None		Nut, Hex, 3/8", N.F. Thread, Steel
6.03.10S2	None		Screw, 3/4", 10-24, Round Head, Brass
6.03.11S4	None		Screw, 1", 6-32, Round Head, Brass
6.03.12S4	None		Nut, Hex, 6-32, Brass
6.03.13-2	6.03.13		Clamp Plates
6.03.14S2	None		Cap Screw, 3-3/8", 3/8" N.F., Steel

Part No:	Dwg. No:	Note:	Description:
6.03.15S2	None		Washer, 7/16" I.D.
6.03.16S4	None		Cap Screw, 1", 3/8" N.F., Brass
6.03.17S2	None		Wing Nut, 10-24, Brass
6.03.18S2	None		Screw, Round Head, 3-1/2", 10-24, Steel
6.03.19S1	None		Way Strip, 6" x 1/8" x 1/2" Steel
6.03.20-2	6.03.20 6.03.21		Focusing Screw
6.03.21-2	6.03.20 6.03.21		Focusing Screw Collar
6.03-22	6.03.22 6.03.25		Focus Screw Rigid Retainer Block
6.03.23S2	None		Screw, Round Head, 3-1/4", 10-24, Brass
6.03.24S18	None		Nut, Hex, 10-24, Brass
6.03.25	6.03.22 6.03.25		Focus Screw Movable Retainer Block
6.03.26-2	6.03.26 6.03.29		Threaded Focus Screw Block
6.03.27S6	None		Pin, 1", 3/8" dia., Steel
6.03.28S5	None		Set Screw, Allen, 1/4", 6-32, Steel
6.03.29-4	6.03.26 6.03.29		Focus Screw Block Bracket
6.03.30S8	None		Screw, Flat Head, 2-1/4", 10-24, Brass
6.03.31	6.03.31		Film Holder Support Plate
6.03.22	6.03.05 6.03.32	B	Clamp Block

Drawing 6.03.00-A

Part No:	Dwg. No:	Note:	Description:
6.03.33S4	None		Screw, Flat Head, 2-1/2", 10-24, Brass
6.03.34S8	None		Screw, Round Head, 1-3/4", 10-24, Brass
6.03.35-2	6.03.35		Film Holder Support Blocks
6.03.36S4	None		Film Holder Support Pins
6.03.37S4	None		Nut, Hex, 10-24, Brass

ASSEMBLY NOTES:

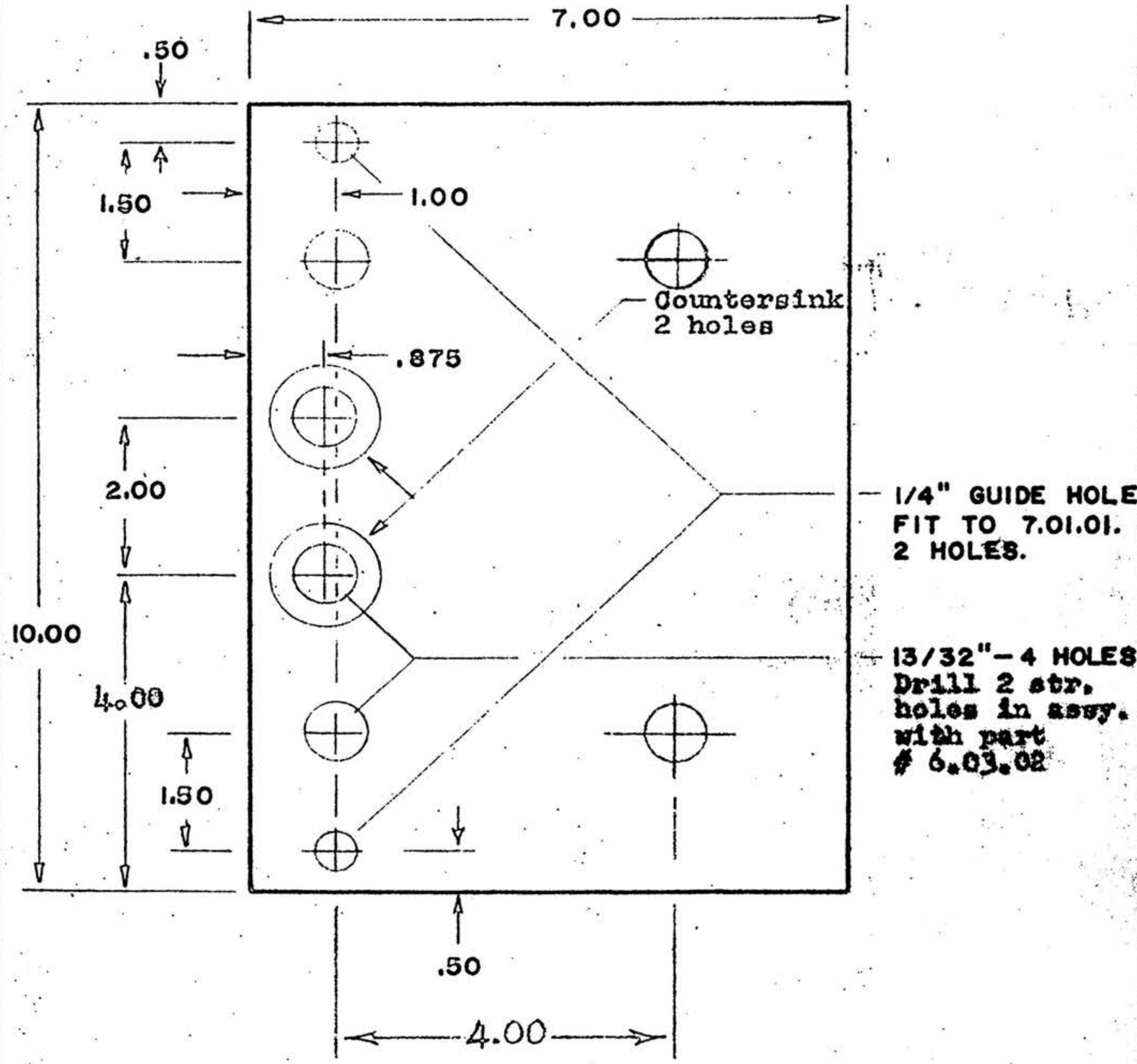
(A)

Assemble mechanism as shown in drawings 6.00.00-B, C and E.

All oil and grease must be removed from all parts. If lubrication is required, Dow Corning high vacuum stopcock grease should be used.

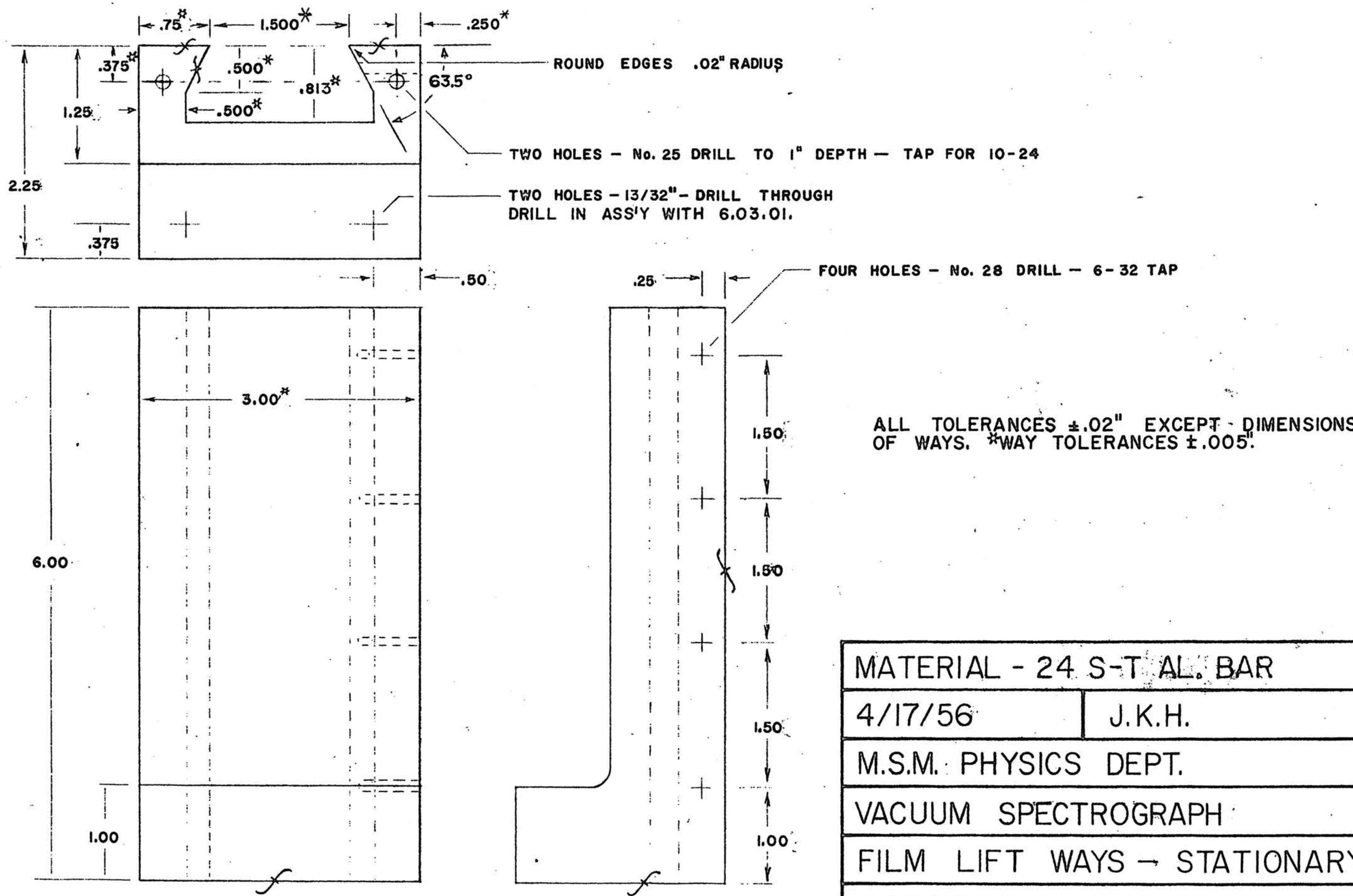
(B)

Screws 6.03.33S4 and nuts 6.03.37S4 are used to hold clamp block 6.03.32 to film holder support plate 6.03.31.

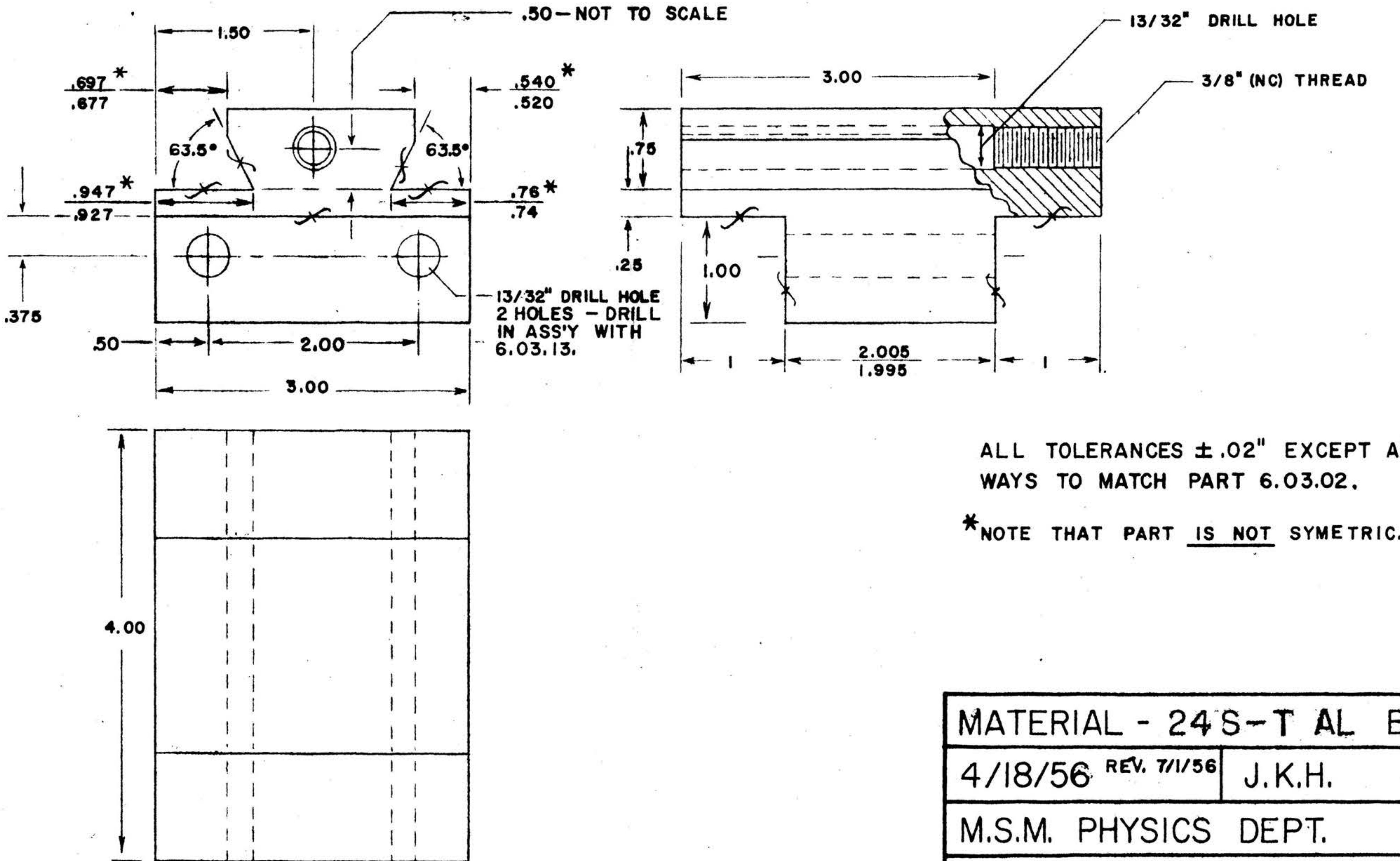


TOL. ± .02"
MATERIAL: 1/2" ALUMINUM
SCALE: 1/2 SIZE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
4/18/56 1/7/56	BASE PLATE
J.K.H	PART No. 6.03.01



MATERIAL – 24 S-T AL. BAR	
4/17/56	J.K.H.
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
FILM LIFT WAYS → STATIONARY	
6.03.02	

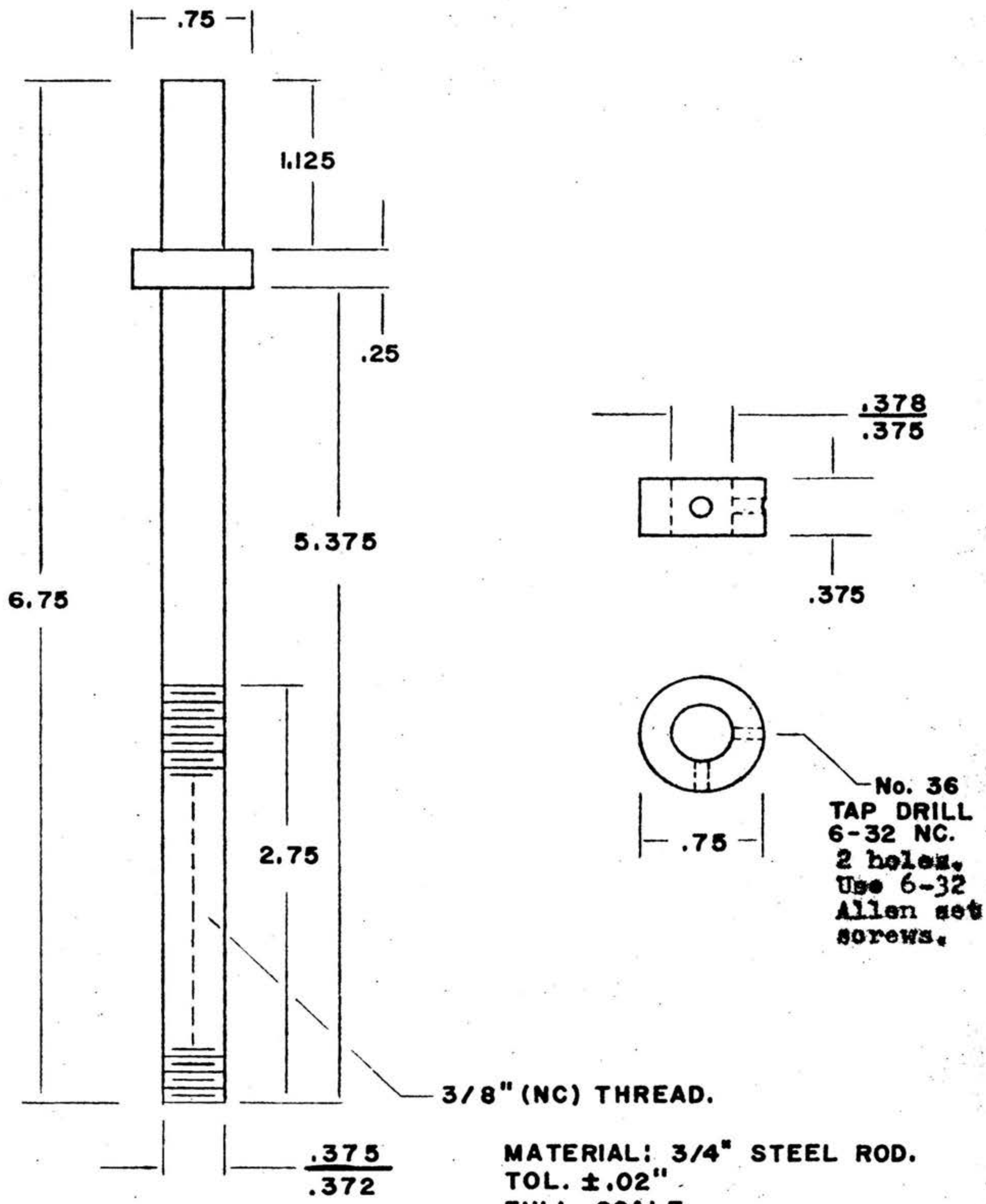


ALL TOLERANCES ± .02" EXCEPT AS NOTED.
WAYS TO MATCH PART 6.03.02.

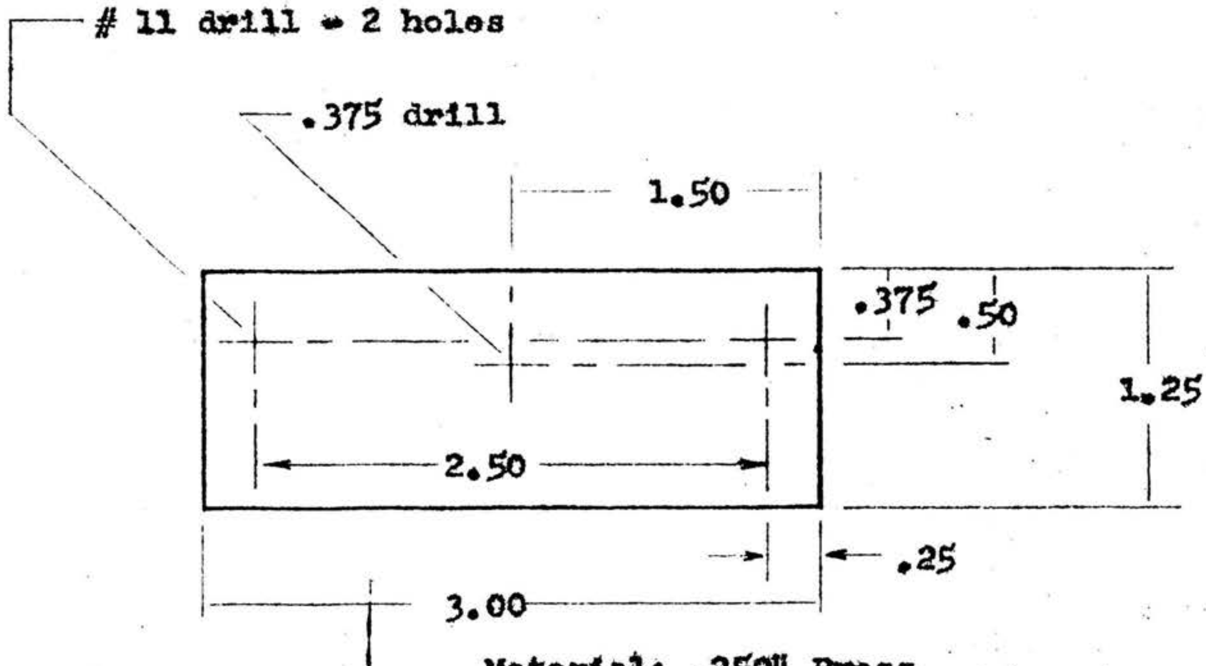
*NOTE THAT PART <u>IS NOT</u> SYMETRIC.

FULL SCALE

MATERIAL - 24 S-T AL BAR	
4/18/56 REV. 7/1/56	J.K.H.
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
FILM LIFT WAY BLOCK	
6.03.03	

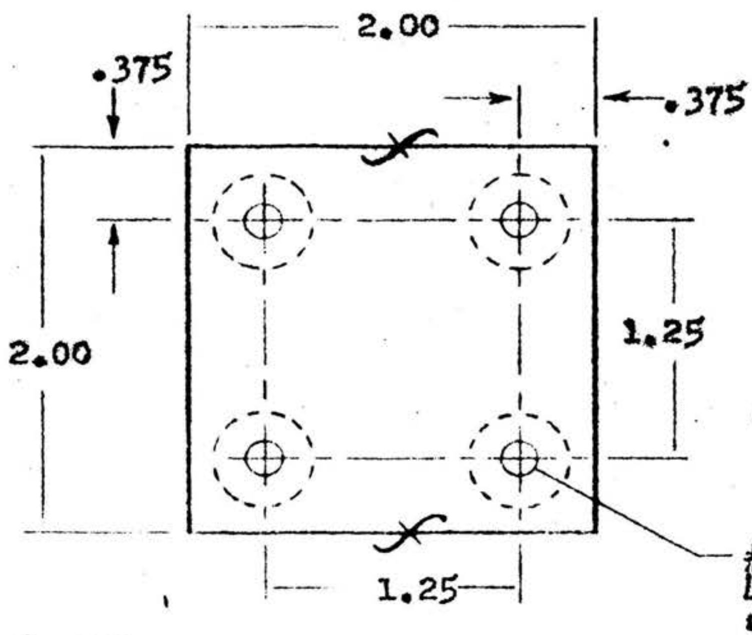


M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
4/20/56	DRIVE SCREW & COLLAR
J.K.H.	6.03.04 & 6.03.06



Material: .250" Brass
Tol. ±.02"

Drive Screw Retainer	Part No. 6.03.05



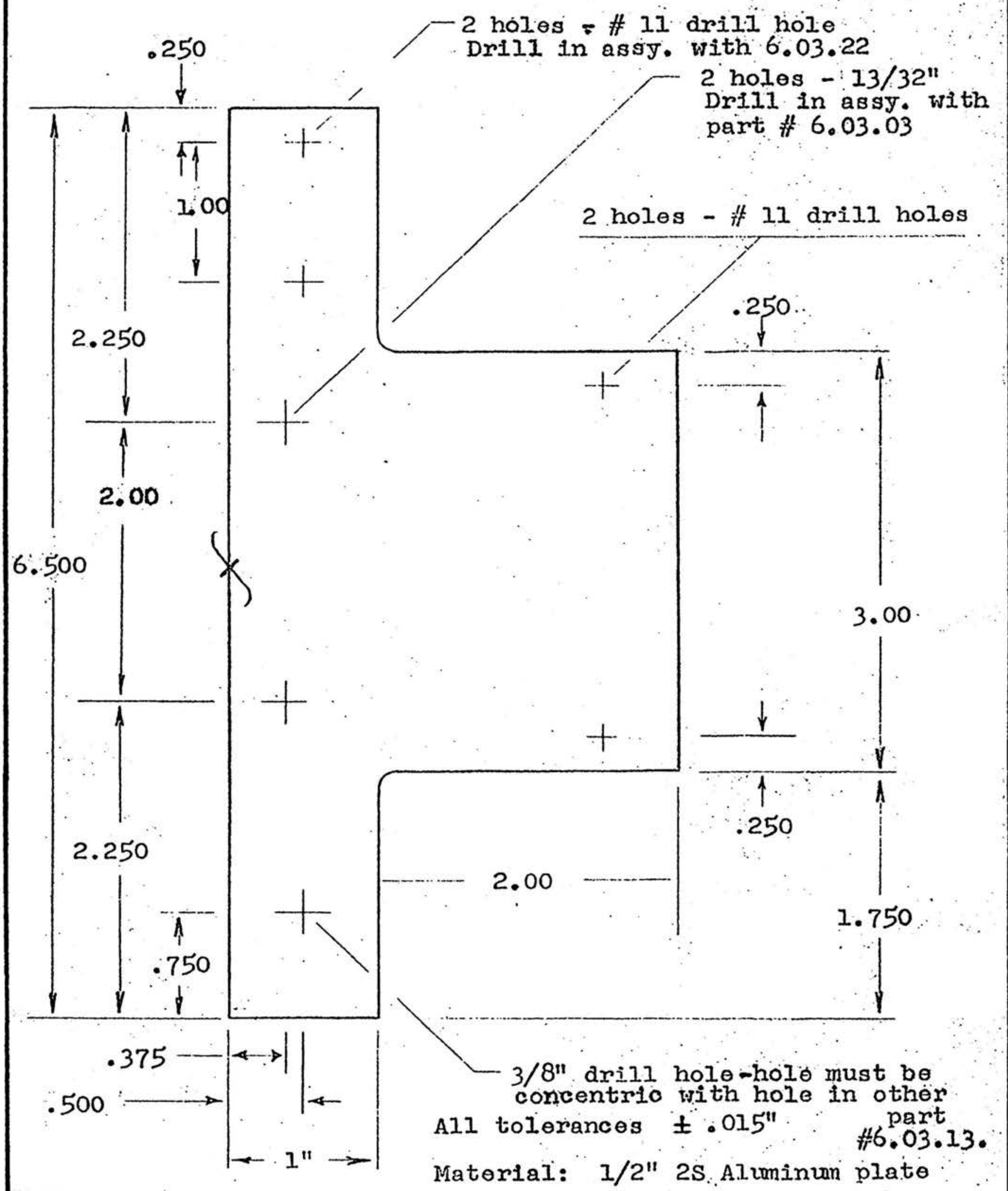
Tol: ± .02"
Material: 2.00" 24S-T Al. Bar.
Block is 2" x 2" X 2".

11 drill holes
4 holes - Drill in ass'y with 6.03.31.
Counterbore holes on back side .50" to .25" depth.

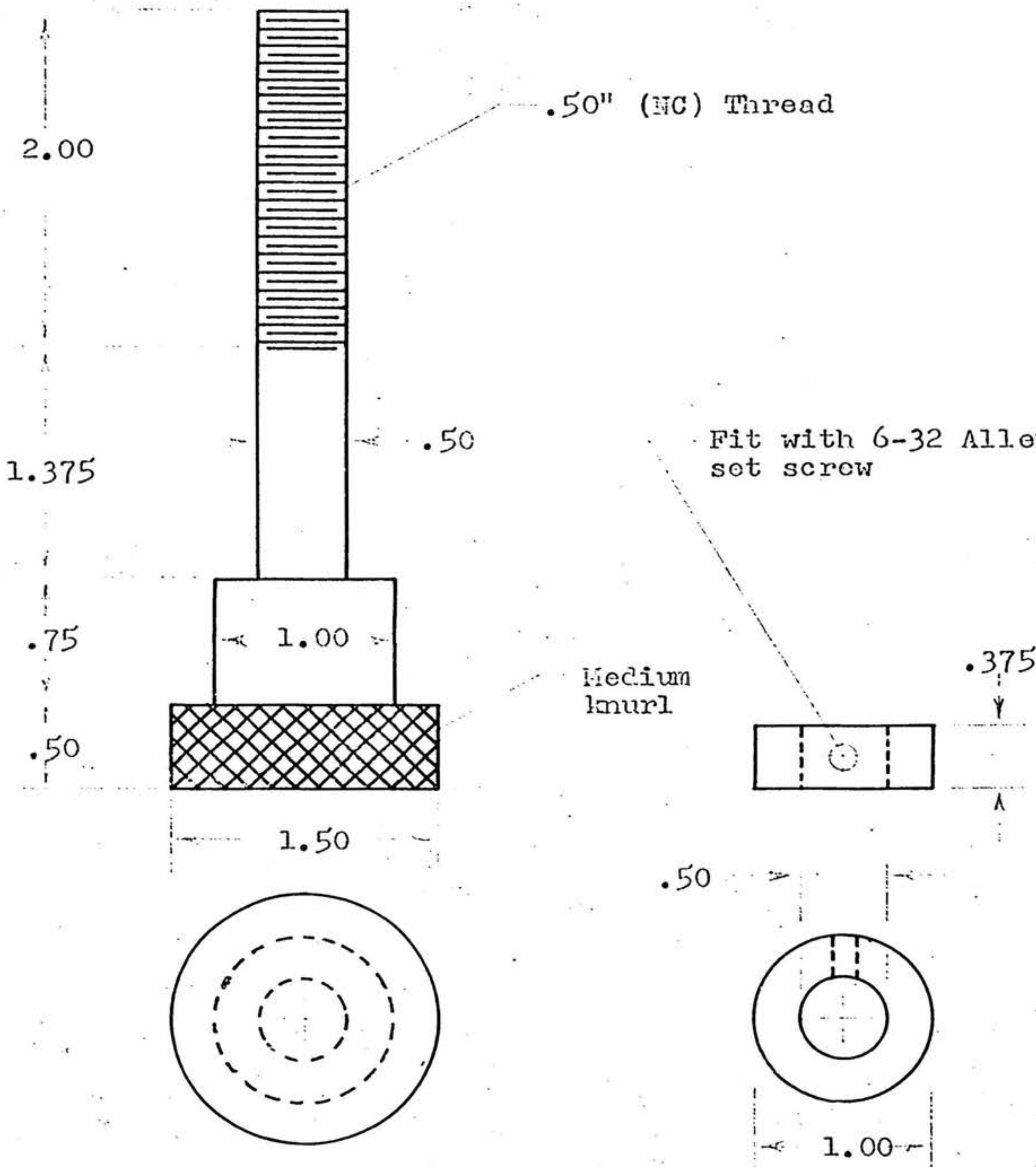
M.S.M. Physics Department

Vacuum Spectrograph

jkh 7/1/56	Clamp Block
	Part No. 6.03.32 -- Also(top) 6.03.05



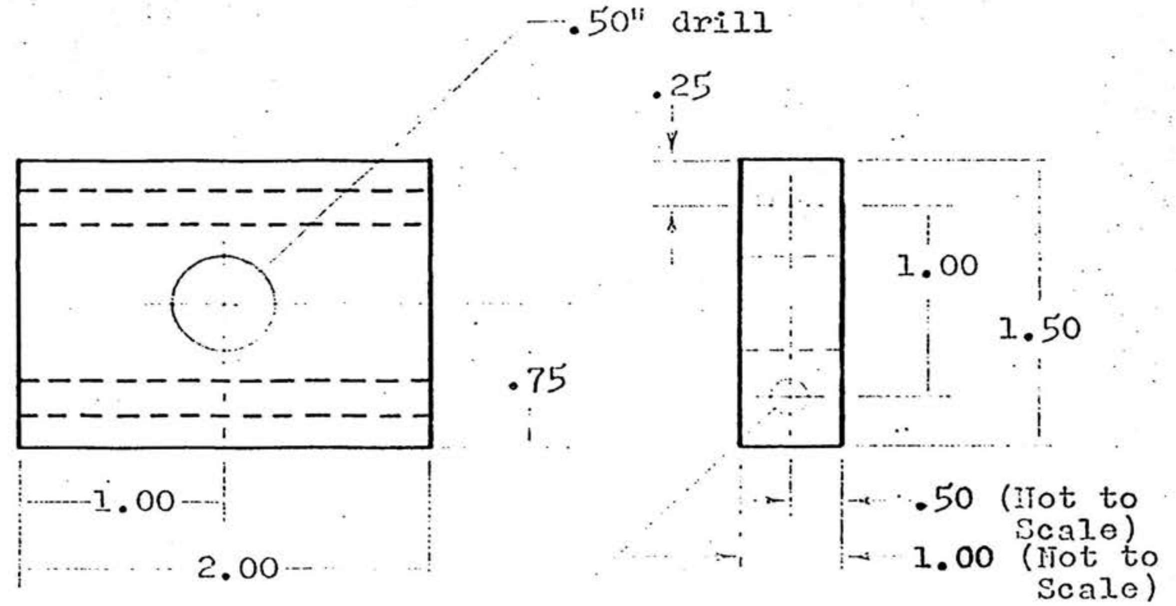
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
4/ 18 / 56 7/1/56	Clamp plate - 2 required
Drawn by J.K.H.	Part # 6.03.13



Tol: ± .02"
Material: 1.50" Brass Rod

Collar Material: 1.00" Brass

Missouri School of Mines and Metallurgy Physics Department	
Vacuum Spectrograph	JKH 7/2/56
Focusing Screw	Part No. 6.03.20 - 2 required
Focusing Screw Collar	Part No. 6.03.21 - 2 required

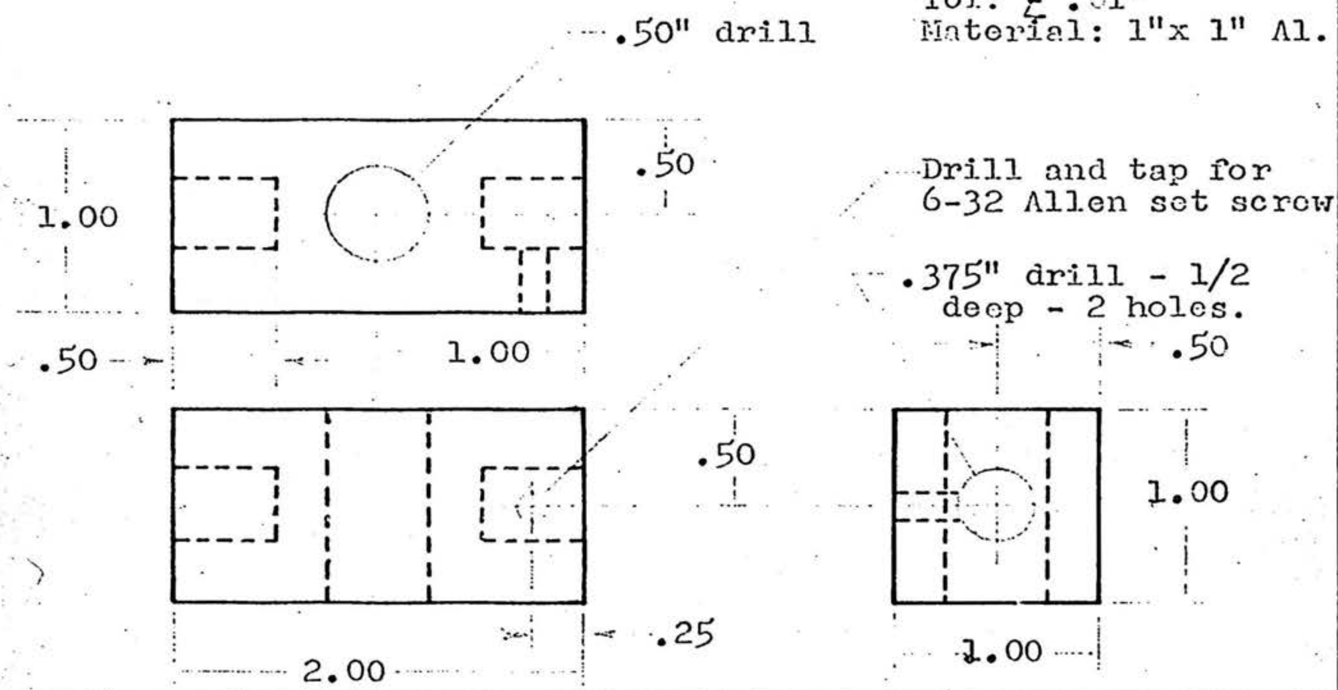


Tol: ± .01
Material: 1.00" Al.

\# 11 drill - 2 holes
drill in ass'y with 6.03.13

Focus Screw rigid retainer block	Part # 6.03.22

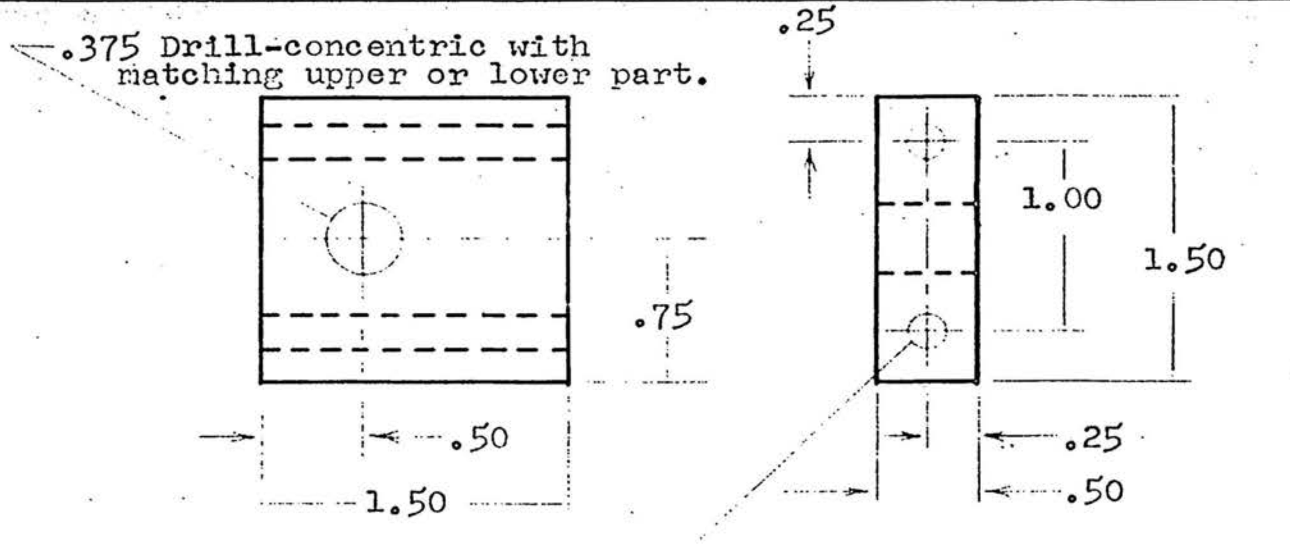
Tol: ± .01"
Material: 1"x 1" Al.



M.S.M. Physics Department

Vacuum Spectrograph

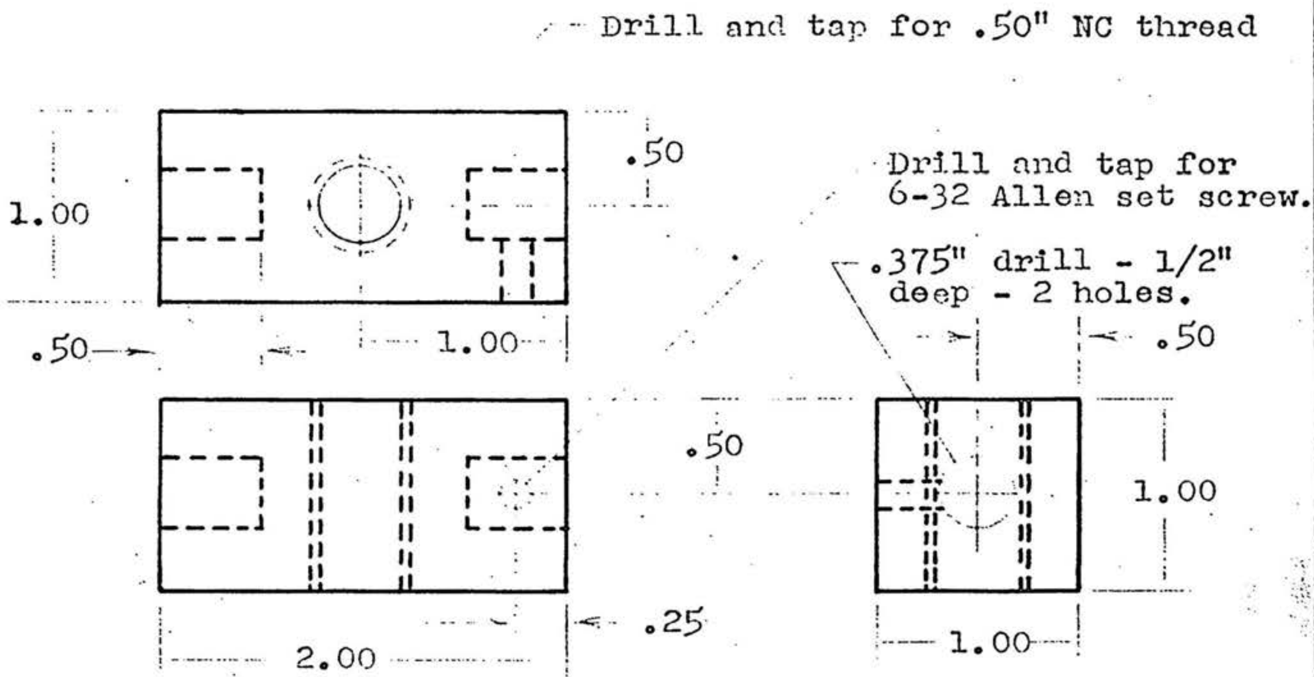
jkh 7/1/56	Focus screw movable retainer
	6.03.25 Also(top) 6.03.22



Tol: ∠ .02"
Material: .500" 3S Al.

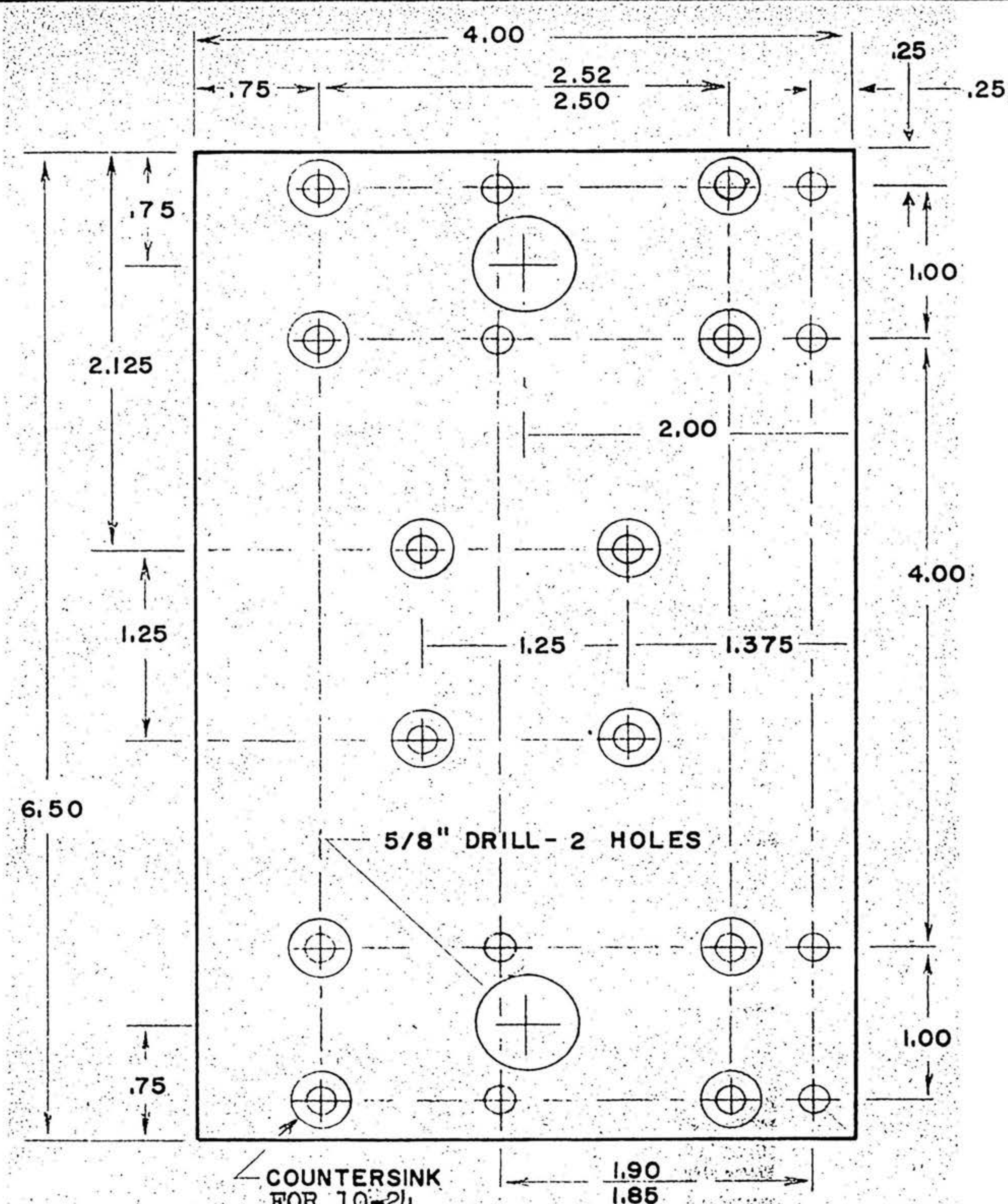
#11 drill - 2 holes - drill in ass'y with 6.03.31.

Focus screw block bracket -- 4 required	Part No. 6.03.29



Tol: ∠ .01"
Material: 1" x 1" Al. bar.

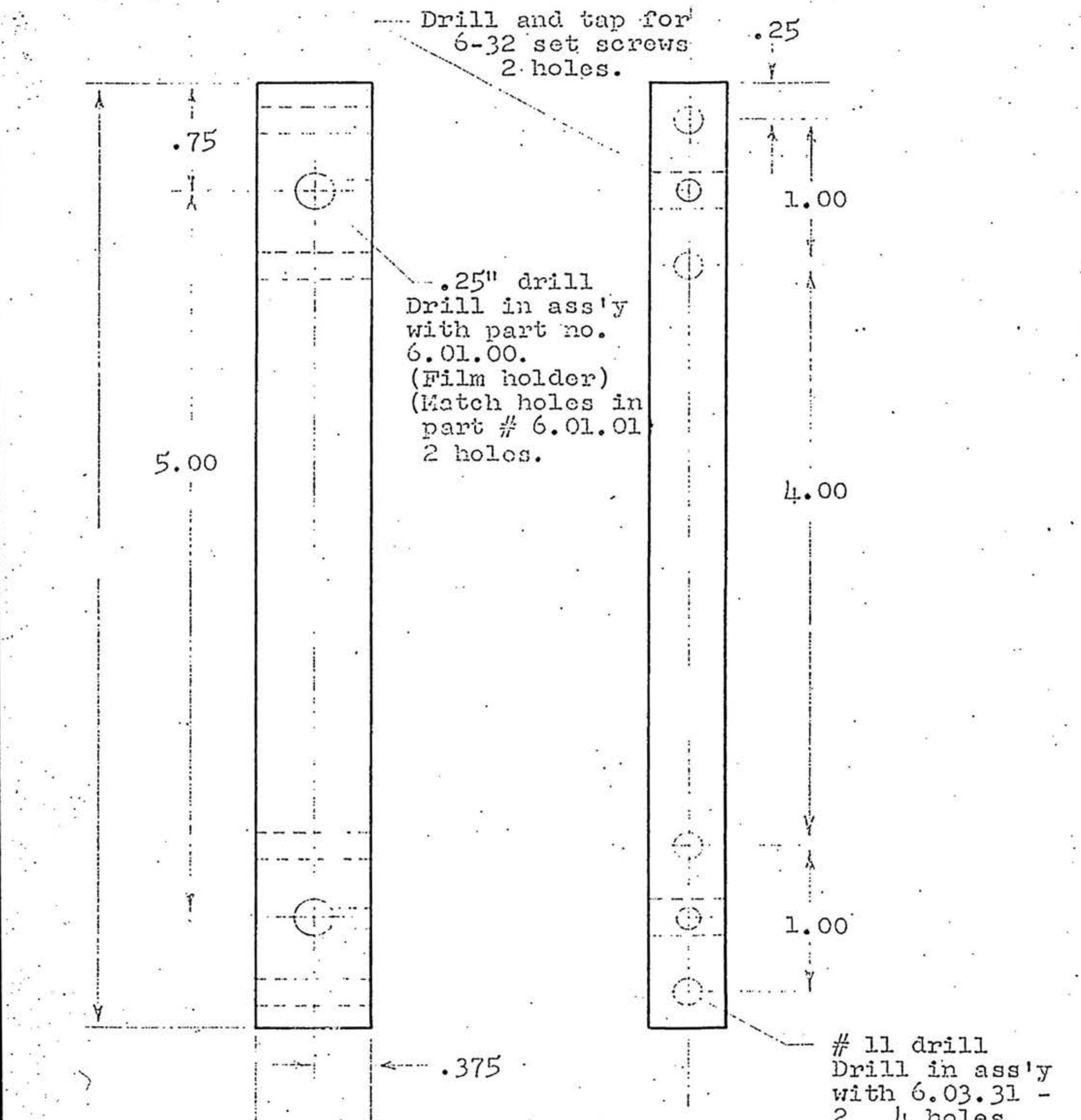
Missouri School of Mines and Metallurgy Physics Department	
Vacuum Spectrograph	
jkh 7/2/56	Threaded Focus Screw Block
	Part No. 6.03.26 -- 2 required



Unless otherwise noted, drill holes with #11 drill. Drill in assembly.

Material: 1/2" Aluminum.
Tol. ∠ .02" Except as noted.

M.S.M. Physics Department	
Vacuum Spectrograph	
4/21/56;1/756	Film Holder Support Plate
J.K.H.	Part No. 6.03.31



Tol: ∠ .02"
Material: .500"x.750" Al. Bar.

Missouri School of Mines and Metallurgy Physics Department

Vacuum Spectrograph

JKH 7/2/56	Film Holder Support Block
Two support blocks are required	Part No. 6.03.35 - 2 required

Drawing 6.04-00-A
Film Drive Linkage
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
6.04.00	6.04.00-A 6.04.00-B	A	Film Drive Linkage Ass'y View
6.04.01-2	6.04.01		Angle Drive Bracket
6.04.02S4	None		Miter Gear-(Boston Gear Co. #L110Y), 1" Pitch Dia., 16 Pitch, 16 Teeth, 0.22" Face, 3/8" Hole, 3/4" ±0.005" Depth, Major Dimension--1-1/16", Hub Dia.--3/4", Hub Projection--7/16" 20° Pressure Angle Steel Miter Gear
6.04.03-4	6:03.06		Collar (3/8" Shaft) (Same as 6.03.06)
6.04.04S1	None		Shaft, Horizontal Drive, 5.750", 3/8" Dia., Steel Drill Rod
6.04.05S1	None		Coupling, 1" Long, 3/8" Shaft, Steel
6.04.06	6.04.06		Crank, Film Drive
6.04.07	6.04.07	1	Flange Ass'y
6.04.08S1	None		Shaft, 1.600" Long, 3/8" Dia. Steel Drill Rod

FABRICATION NOTES:

(1)

Remove rubber parts from inside the vacuum seal while soldering seal to flange.

ASSEMBLY NOTES:

(A)

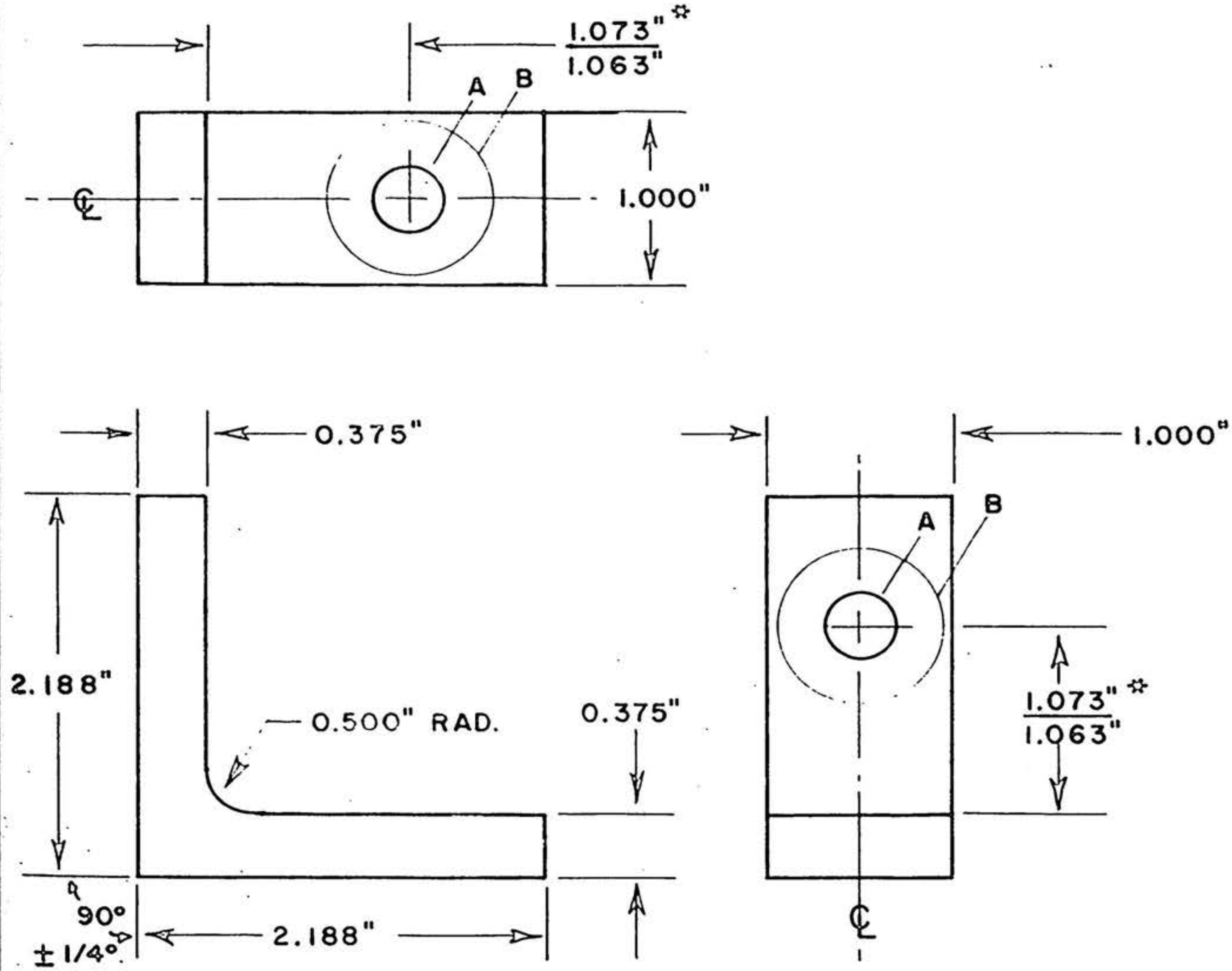
Assemble the drive linkage as shown in drawing 6.04.00-B. A standard 6" vacuum gasket is used between the flange surfaces. See section 8.00.00.

All oil and grease must be removed from all parts. If lubrication is required, use Dow-Corning high vacuum stopcock grease.

A – 25/64" HOLE

B – FACE SMOOTH – BOTH SIDES – 7/8" DIAM. FACES //.

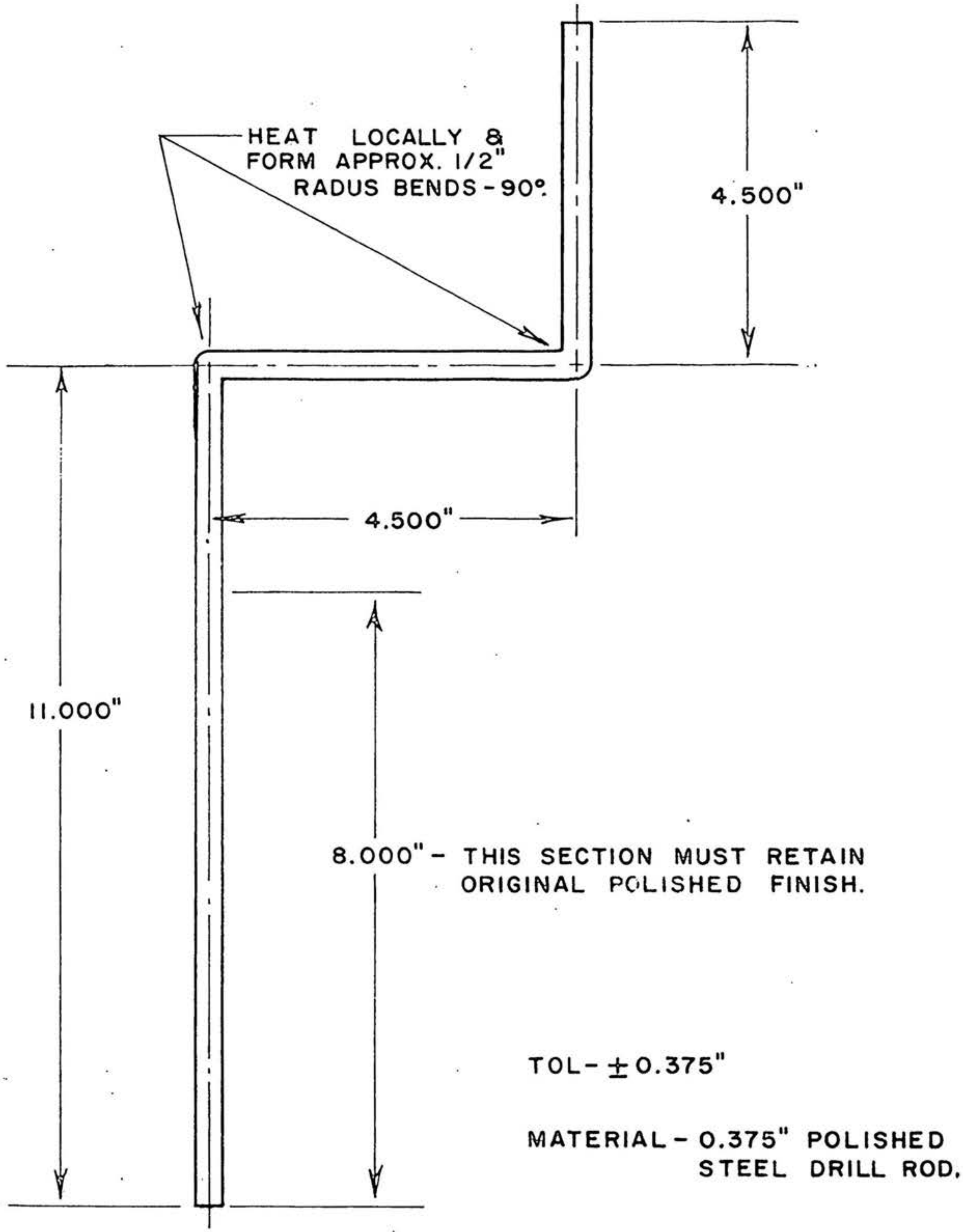
*DISTANCE FROM FACED SURFACE.



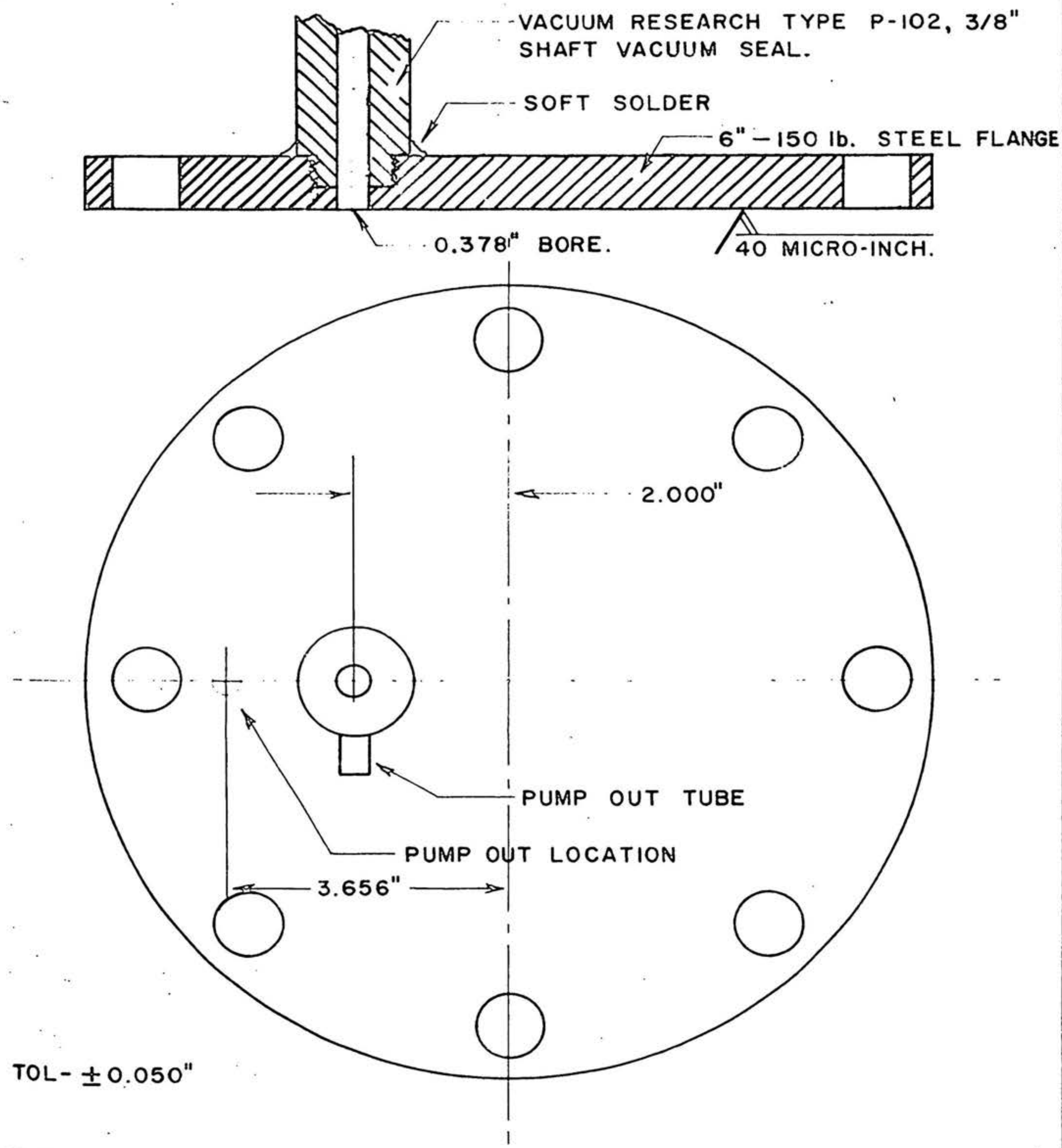
TOL – ± 0.015"

MAT. 7075 T6 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	ANGLE DRIVE BRACKET
	6.04.01-2



M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	CRANK, FILM DRIVE
	6.04.06



M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	FLANGE ASSEMBLY
	6.04.07

7.00.00: MOUNTING PLATFORM

7.01.00: Platform Design Considerations

7.01.01: Platform Concept

All internal equipment of the spectrograph is mounted on a removable, yet positively indexed, mounting platform consisting of a frame and separately removable mounting plates. This platform serves both as a convenient mounting surface for internal equipment and as an accurate reference base for the entire instrument.

The removable mounting platform and reference base is believed to be an innovation in this type of instrument. Although it is considerably more elaborate than conventional mounting schemes, it has several advantageous features that contribute significantly to increased flexibility and convenience. First, mounting and alignment holes drilled at a series of accurately known and evenly spaced locations allow various parts to be installed or removed quickly and precisely. Second, a wide variety of equipment may be mounted without the inconvenience and damage caused by drilling new holes in the basic instrument. Third, initial alignment may be done mechanically with great accuracy if the center of the Rowland Circle is marked accurately on such a mount. Fourth, the platform may be supported only at the ends thus greatly simplifling the mounting in the vacuum chamber. Fifth, equipment may be mounted near the center of the platform prior to insertion into the vacuum chamber thus minimizing the requirements for working inside the chamber.

7.01.02: Grazing and Normal Incidence Requirements

In order to allow practical use of the instrument at grazing incidence in the manner described in section 4.03.04, the section of the mounting platform top plate supporting the grating mount and the grazing incidence plate holder was designed to be removable. This feature makes it possible to remove the entire grazing incidence apparatus for service without loss of the critical grating-detector alignment or possible grating damage. Positive indexing of the plate assures conservation of grating-light source alignment for this configuration and grating-dectector alignment for the arrangement described in section 4.03.03.

Similar considerations made the use of a removable mounting plate at the normal incidence detector end equally desirable. As a wide variety of normal incidence detection equipment was anticipated, the design required easy installation and alignment of such apparatus.

7.01.03: Addition of Other Mounting Plates

Although it is possible to mount a wide wariety of apparatus on the existing mounting plate, it is likely that some experiments may require such plate modifications as to destroy established critical alignments. The removable plate system makes it possible to substitute different mounting plates for different experiments. Such substitutes should be used whenever mounting requirements are such as to endanger the original plate and its precise alignment and reference lines.

When substitute mounting plates are installed, the same alignment pin holes in the frame should be used. However, the matching holes in the new plates should be drilled through the existing holes in the frame. These holes should never be pre-drilled with the intention of reaming the frame pin holes. Such reaming would ruin them for further use with the original or other plates. The entire frame assembly must be removed from the vacuum chanber in order to drill alignment pin holes.

7.01.04: Design of Additional Base Plates

When possible, it is desirable to design all base plates to utilize the existing mounting holes. Alignment pin holes should always be drilled through the existing mount plate holes so as not to destroy their accuracy for indexing of existing equipment.

7.02.00: Platform Description

7.02.01: Platform Girder (7.01.00)

The various internal mounting requirements discussed in section 7.01.00 were satisfied by the use of a 72 inch, removable mounting platform. This platform is shown installed in the vacuum chamber with equipment installed on it in figures 7.02.01 A & B. The basic part of this platform is the platform frame assembly (P/N 7.01.00) shown in figure 7.02.01-C. This frame is made entirely of aluminum in order to reduce weight and to avoid rust and consequent outgassing. It is securely bolted and pinned together in order to provide a rigid and stable base for mounting internal equipment.

The frame assembly is supported at both ends by, and pinned to, two support blocks (8.02.06 and 8.02.07) that are firmly attached to the inside wall of the main vacuum chamber (8.02.00). The entire frame assembly may be removed via the grating mount end opening after loosening the four 7.01.09S4 screws and removing pin 7.01.10. This feature makes it possible to assemble and adjust most of the internal spectrograph equipment on the bench prior to installation in the vacuum chamber. This same feature also frees the vacuum system for other uses when this platform is removed.

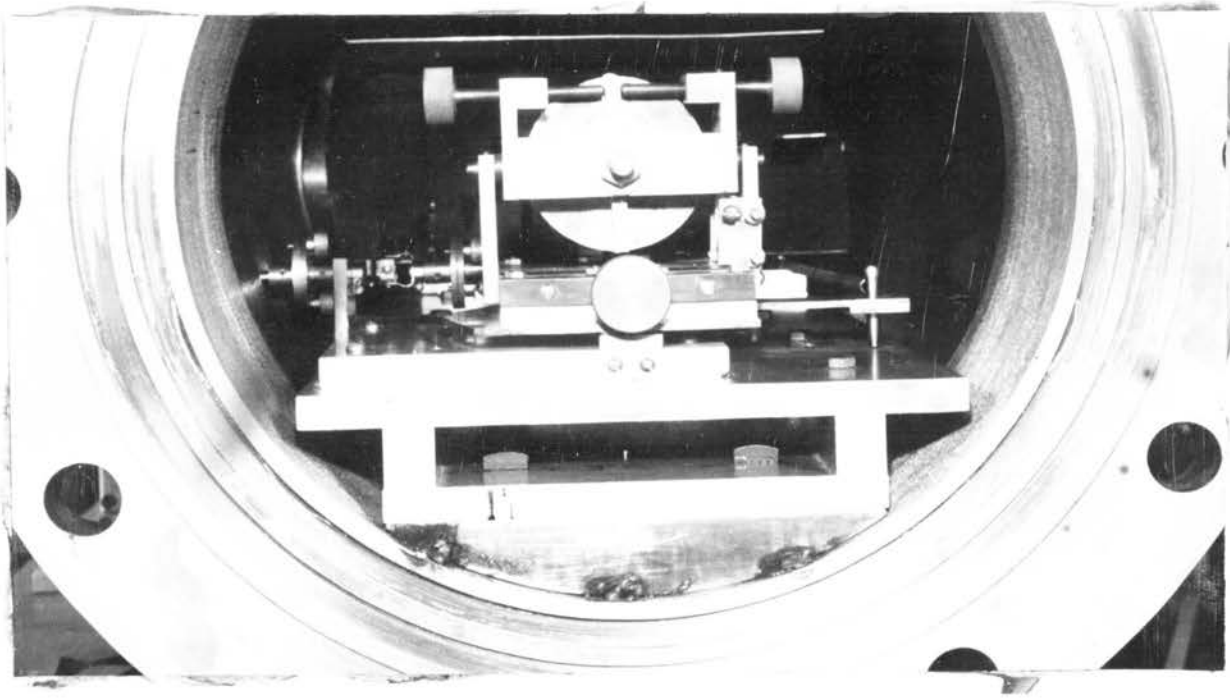


Figure 7.02.01A: Platform Installed in Vacuum Chamber
(Grating End)

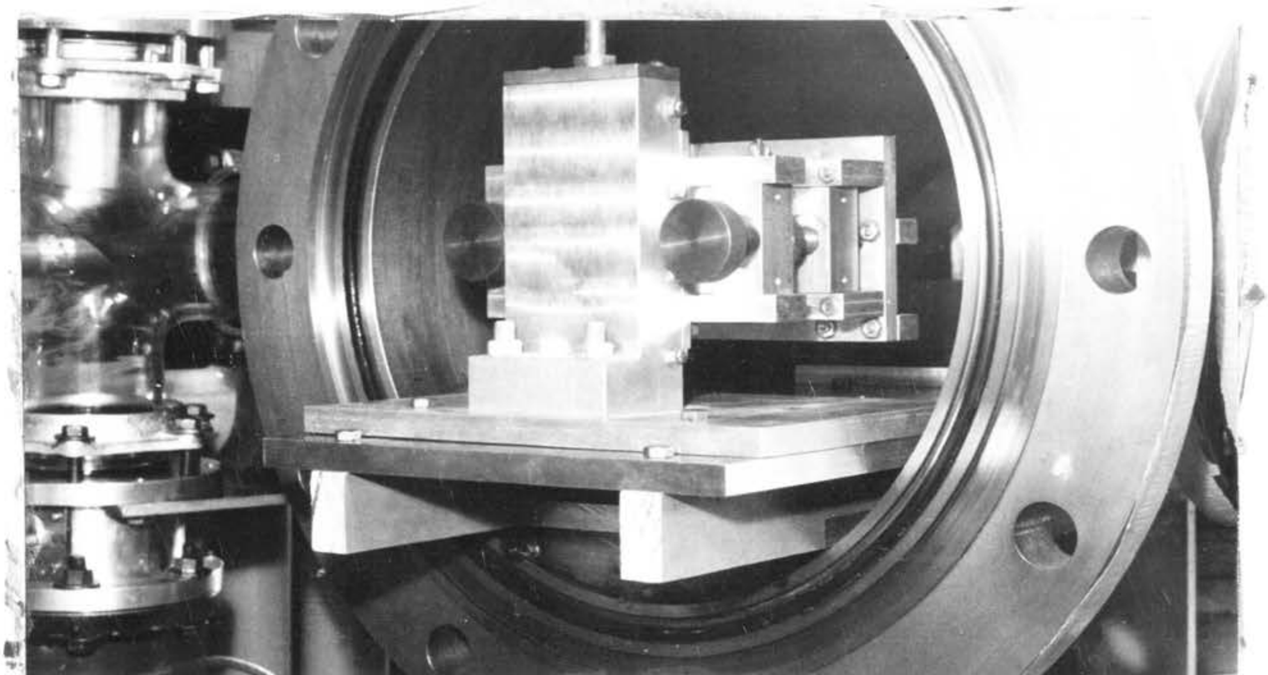


Figure 7.02.01B: Platform Installed in Vacuum Chamber
(Detector End)

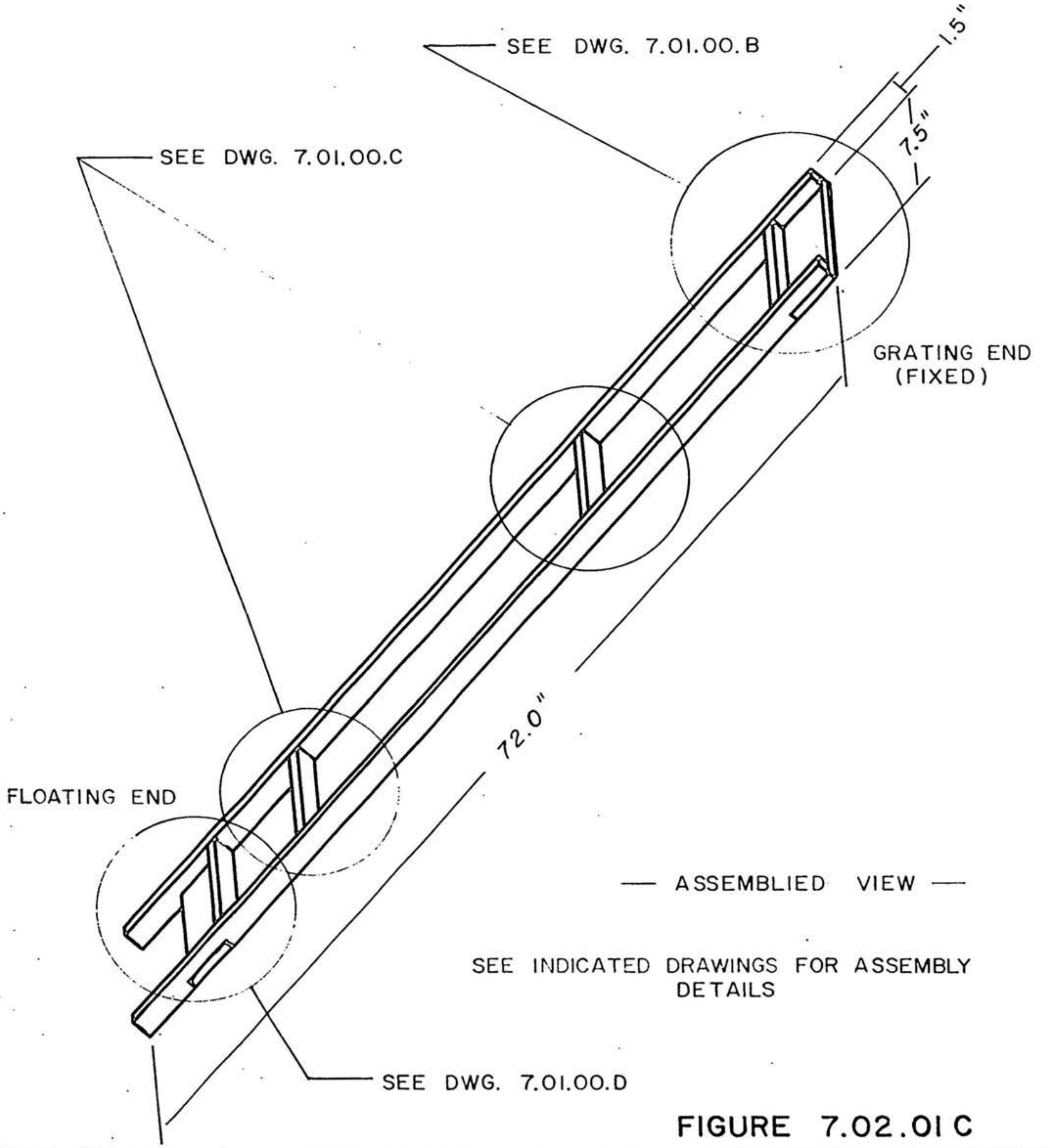


FIGURE 7.02.01 C

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 6/26/57	PLATFORM FRAME ASS'Y.
	7.01.00.H

7.02.02: Rowland Circle Center Reference Assembly (7.03.00)

Between station lines 28.000 and 32.000, the Rowland Circle Center Reference Plate (P/N 7.03.01) is permanently bolted and pinned to the mounting platform frame assembly. A 0.250 inch hole drilled through this plate and center reference block 7.03.04 at station 29.415, position +2.576 locates the center of the normal incidence focal circle. The center of this hole is located 29.528 inches (75 cm) from the center of the grating surface and the surface of the photographic plate in the film holder. This reference hole serves as an axle point for a swinging, 75 cm long reference arm (P/N 7.03.06) that is installed inside the spectrograph during rough alignment. This arm, when adjusted to a 75 cm length, provides a convenient measuring device for rough focusing and location of apparatus relative to the focal circle.

7.02.03: Grating End Mounting Plate (7.02.01)

The grating mount and all of the internal portions of the grazing incidence spectrograph are mounted on the grating end mounting plate (7.02.01). This 10 by 32 inch plate of 0.500 inch aluminum is mounted on the frame assembly between station lines -4.000 and +28.000. This plate and any equipment located on it may be removed from the vacuum chamber without loss of alignment. The only tool required is an Allen wrench to remove the ten 7.02.02 1/4" screws holding the plate to the mounting frame. The four alignment pins must be pulled and the grating drive decoupled before removal of the mounting plate. All alignment pins and mounting screws are accessible through either the 14 inch end opening or the 6 inch access port at station line 16.625.

Correct alignment of the mounting plate relative to the platform frame and the remainder of the instrument is maintained by four alignment pins (7.02.03). Retention of alignment should be possible even in the extremely critical case of the grazing incidence spectrograph. This indexing provision makes it possible to remove the grazing incidence components from the vacuum chamber for most alignment and servicing tasks. The use of an appropriate arm to support the 7.03.06 alignment tool would allow rough grazing incidence focusing to be made in the removed condition.

The 7.02.01 mounting plate is located so that the grating center reference hole at (0.000, 0.000) is 29.528 $\pm$0.005 inches (75 cm) from the center of Rowland Circle center reference hole at (29.415, $+$2.576). All alignment holes in both the plate and supporting frame are within $\pm$0.015 inch of the indicated positions as measured from the (0.000, 0.000) point.

7.02.04: Detector End Mounting Plate (7.04.01)

The detector end mounting plate supports the normal incidence detection equipment and the mask assembly. This plate, located between station lines +43.000 and +68.000, is designed for easy removal from the frame assembly and the vacuum chamber. Removal may be accomplished after removing screws 7.04.02S10 at station lines 44.000, 51.000, 56.000, 64.000 and 67.500 and knurled alignment pins 7.04.03S4 at station lines 46.000 and 65.000. All screws and pins are accessible through either the 14 inch end opening or the 6 inch port at station 54.623. If the film positioner is in use, it may be necessary to disconnect the film drive linkage. (See section 6.03.04.)

The four alignment pins make it possible to remove the mounting plate from the chamber and then return it to the correct position. This feature permits most installation and adjustment operations to be performed under the more accessible conditions of the work bench instead of inside the vacuum chamber. The accurate indexing makes it possible to place accurately equipment on the mounting plate prior to its installation in the instrument. The locations of all mounting reference lines are accurate to within ±0.015 inch relative to position (0.000, 0.000). This accuracy is obtained by careful measurement of these distances from the zero reference at the time that the plate is clamped for drilling of the alignment pin holes.

7.03.00: Platform Installation and Alignment

7.03.01: Normal Platform Frame Installation

With both of the vacuum chamber ends removed, the assembled platform is inserted from the grating end of the vacuum chamber. The frame is slid along on support block 8.02.06 until the 0.500 inch pin in the center of the block 8.02.07 is in the mating slot in frame mounting plate 7.01.04. The free end of the platform is shifted until pin 7.01.10 can be pushed into place through the center hole in mounting plate 7.01.03 and support block 8.02.06.

Caution: If the grating mount is already installed, this pin must be inserted in plate 7.01.04 from the bottom prior to placing the platform into the chamber.

Hold down screws 7.01.09S4 are then tightened.

7.03.02: Initial Platform Installation

At the time of initial installation, the 0.253 inch hole must be drilled in support block 8.02.06 to receive alignment pin 7.01.10. With the grating end mounting plate (7.02.01) installed on the frame assembly, it is bolted to the support blocks in a position such that the center of the grating center hole (hole E on plate 7.02.01 at 0.000, 0.000) is 4.375 $\pm$0.015" from the surface of the grating end flange surface and is centered laterally inside the vacuum chamber to within 0.025 inch of a line in the vertical plane that contains the main chamber center line and is perpendicular to the horizontal plane containing the main chamber center line and the center line of the two inch pipe at S. L. 26.080. The grating end mounting plate (7.02.01) is then removed and the 0.253" index pin hole in support block 8.02.06 drilled using an 0.250" drill and an 0.253" ream. Index pin 7.01.10 is then installed in the hole.

7.04.00: Platform Construction

All detailed information required for part fabrication and assembly of the frame assembly and the installation of the mounting plates is given by the series 7.00.00 drawings at the end of this section. See drawing 7.00.00-A. Assembly drawing 7.01.00-A is included in this section as figure 7.02.01-C.

Drawing 7.00.00-A
Mounting Platform
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y. No:	Dwg. No:	Note:	Description:
7.00.00	7.00.00-A		Mounting Platform Ass'y.
7.01.00	7.01.00-A		Platform Frame Ass'y.
7.02.00	7.02.00-A		Grating End Mounting Platform
7.03.00	7.03.00-A		Center Reference Plat-form
7.04.00	7.04.00-A		Detector End Mounting Platform

Drawing 7.01.00-A
Platform Frame Assembly
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
7.01.00	7.01.00-A 7.01.00-B 7.01.00-C 7.01.00-D 7.01.00-H	(A)	Platform Frame Ass'y. Grating End Detail Cross Member Detail Floating End Detail Perspective View of Ass'y.
7.01.01-2	7.01.01	(1)	Longitudinal Member
7.01.02-4	7.01.02	(2)	Cross Member
7.01.03	7.01.03 7.01.04	(3)	Mounting Plate-(Fixed End)
7.01.04	7.01.03 7.01.04	(3)	Mounting Plate-(Floating End)
7.01.05S8	None		Pin, 1-1/2", 0.250" dia., polished steel
7.01.06S8	None		Screw, 1-1/8", 1/4" N.C., brass, thin hex head
7.01.07S8	None		Screw, hex head 1-1/4", 1/4" N.C., brass
7.01.08S16	None		Pin, 1-1/2", 3/16" dia., steel
7.01.09S4	None		Screw, socket head, 1", 1/2" N.C., brass
7.01.10S1	None		Pin, 1-3/8", 0.250" dia., polished steel

FABRICATION NOTES:

(1)

The two 0.500 by 4.000 inch mill cuts between station lines -4.000 and 0.000 and between 59.250 and 63,250 are to accommodate platform mounting plates 7.01.03 and 7.01.04. Although the nominal depth of these cuts is 0.500", material variations may require slight deviations from this value. Overall requirements for the assembled platform (7.01.00) are that the vertical distances from the bottom of platform mounting plates 7.01.03 and 7.01.04 to the top surface of the frame ass'y. be 1.500" ±0.015". This tolerance should be held even if thickness of the material varies. This vertical distance requirement of 1.500" applies to the entire top surface plane of the assembled frame. Hence, the material used must be free of bow to within ±0.015". The top surface of these members must be free of any raised spots caused by dents in the edges or burrs from drilling.

The four mill cuts in the top edge are only for screw head clearance, and their exact location, width and depth is not critical.

It is essential that the ±0.015" tolerances be held on all hole centers except the 3/16" "D" holes through the side of the member.

The 0.250" "B" holes require special attention during fabrication. These holes serve as accurate dimensional references and accommodate the 0.250" index pins. As these pins are removable, the holes must be straight to minimize binding.

Although the four "C" holes through the sides of the member are shown on the center line, they should be located 0.750 ±0.015" from the top edge if the material thickness varies from the 1.500" nominal value.

(2)

Although the threaded holes in the ends of the member are shown on the center line, the distance from one edge (the edge to become the top in the assembled frame) should be 0.750" ±0.015" if the material thickness varies from the nominal 1.500". This is necessary in order to insure a flat top surface for the finished platform.

FABRICATION NOTES (Cont'd)

It is essential that the ends of these members be milled smooth and square so that the longitudinal members will not lean or be twisted in the assembled frame. Such twisting of these members could destroy the flatness of the top of the finished platform frame.

Although the length of the member is given as 6.000", variation from this is permissible if the thickness of the longitudinal member material varies from the nominal 0.750" thickness. However, if such variation is in such a direction as to thicken the longitudinal member, it is preferable to spot machine the excess from the inner side of the member, as such an operation also makes it possible to obtain an exactly 90 degree angle between the side and top of the member. In any case, the length of the cross member is critical. It must be such as to give a distance between the holes in the longitudinal members of 6.750" ±0.015". Overall width of the frame is not critical.

Each cross member has four additional holes that are not shown in the drawing. These are the 3/16" pin holes that are drilled in assembly through the 3/16" "D" holes in the longitudinal members. Drilling instructions are given as a part of the assembly instructions. See Note A.

(3)

Parts 7.01.03 and 7.01.04 differ only in that the center slot is omitted in part 7.01.03, and the hole is omitted in part 7.01.04.

Four holes for the 0.250" pins used to pin these plates to the longitudinal members are not shown in the drawing because these holes are drilled during assembly. These holes are drilled through the holes at station lines -3.625, -0.375, +59.625 and +62.875.

Thickness of these plates is critical, as they contribute to the overall thickness of the mounting platform frame at the mounting points. Thus, the thickness should be such as to give an overall frame thickness of 1.500" ±0.015". (See fabrication note 1.)

FABRICATION NOTES (Cont'd):

Location of the screw holes at the ends of the plates is given as 0.375" from the edge of the plate. Spacing of these holes (center to center) must be 6.750" ±0.015" in order to give correct spacing of the longitudinal members (7.01.01-2). (See Note 2.)

ASSEMBLY NOTES:

The platform frame assembly is assembled in accordance with drawings 7.01.00-B, C, D and H.

In order to obtain the desired flatness of the mounting table frame top side, certain assembly precautions are necessary. (An overall flatness of ±0.015" is required for the top surface of the frame assembly.)

As the frame is to be supported only at the two ends, it is essential that internal stresses be eliminated in order to prevent self induced twisting. Such troublesome stresses can be avoided by making sure that all of the parts fit together perfectly before being bolted and pinned. All joints should be carefully fitted before any bolts or dowel pins are installed.

In order to insure flatness of the top surface, the frame should be assembled top side down on a flat surface. (The ways of a flat bed lathe could be used.)

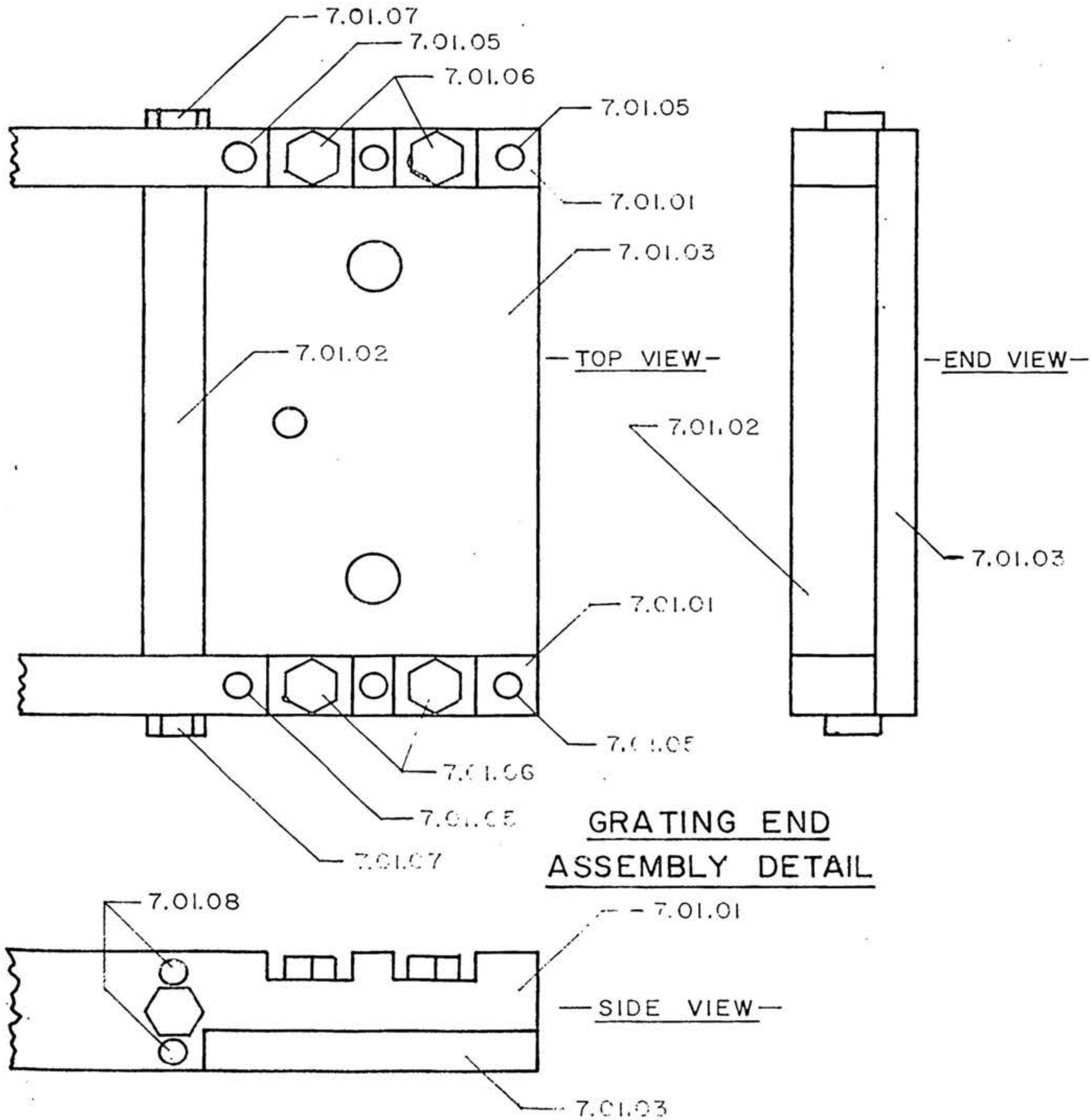
The first step in the assembly is the mating of the two longitudinal members (7.01.01) and the four cross members (7.01.02-4) to form the frame. These parts are assembled upside down on a flat surface plate in order to insure flatness of the top surface of the finished frame assembly. After these parts are fitted in their proper places, they are clamped securely to the surface plate. The cross member tie screws (7.01.07S8) are then installed. After these screws are tightened, the clamps are then released, and the top surface is checked for warpage.

ASSEMBLY NOTES (Cont'd):

The next step in the assembly is the installation of dowel pins 7.01.08S16 that hold the cross member in place. The 0.750", 3/16" dia. holes in the cross members are drilled through the matching holes in the longitudinal members. The frame should be securely clamped (top side down) to the surface plate during this drilling. The dowel pins must be inserted before the clamps are removed.

The assembled frame is then turned right side up on the surface plate and the two frame mounting plates (7.01.03 & 7.01.04) are installed at the ends of the frame. These plates and the frame are assembled right side up, so that the bottoms of these plates rest flatly on two flat spacer blocks placed on the surface plate. Spacer blocks are necessary to prevent the frame assembly from being supported at other points. The mounting plates are carefully fitted to the longitudinal members so that they are in their proper positions and no warping occurs when screws 7.01.06 are tightened. The plates and the frame should be securely clamped to the surface plate during the tightening of these screws. With the platform still clamped in place, the 0.250" holes for the dowel pins (7.01.05) are drilled, and the pins are installed. The holes for these dowel pins in parts 7.01.03 and 7.01.04 are drilled through the matching holes in parts 7.01.01.

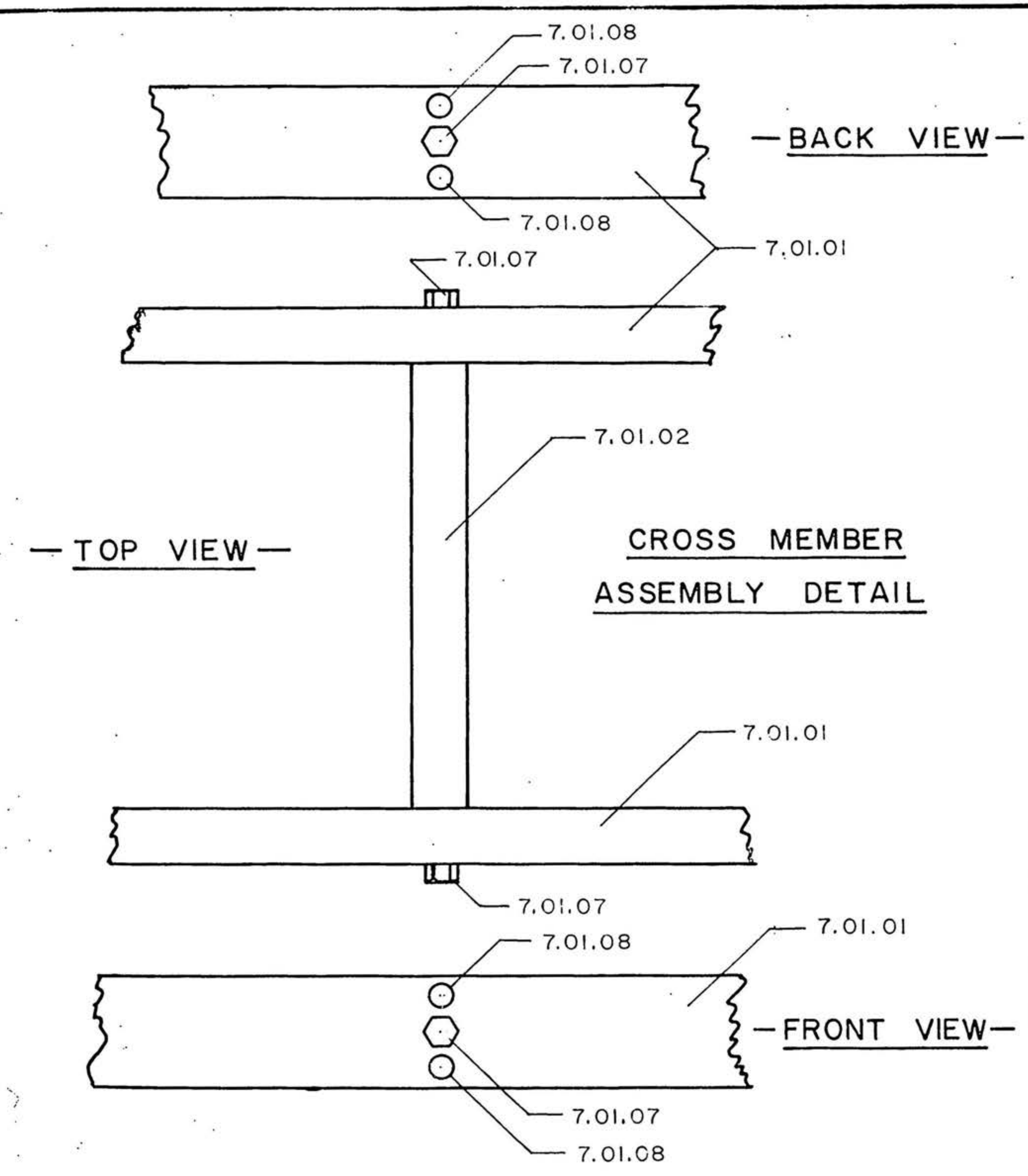
The two mounting plates must be so installed that the 0.250" pin hole in part 7.01.03 and the slot in part 7.01.04 are within 0.015" of the center of the frame. The hole in part 7.01.03 must be within 0.015" of station line -1.000 as defined by the 0.250" alignment pin holes in the top of the longitudinal members of the frame. It is also necessary that the overall thickness of the frame at the mounting plates be held to 1.500" ±0.015". It is essential that the bottom surfaces of the two end mounting plates lie in the same plane. Failure to meet this requirement would cause bowing or warping of the platform frame when it is bolted to the mounting blocks inside the vacuum chamber.



NOTES: (1.) DRILL 2nd. HOLES FOR DOWEL PINS [redacted] AFTER ASSEMBLY.
(2.) TOP OF PLATFORM MUST BE FLAT. ASSEMBLE ON SMOOTH, FLAT TABLE.

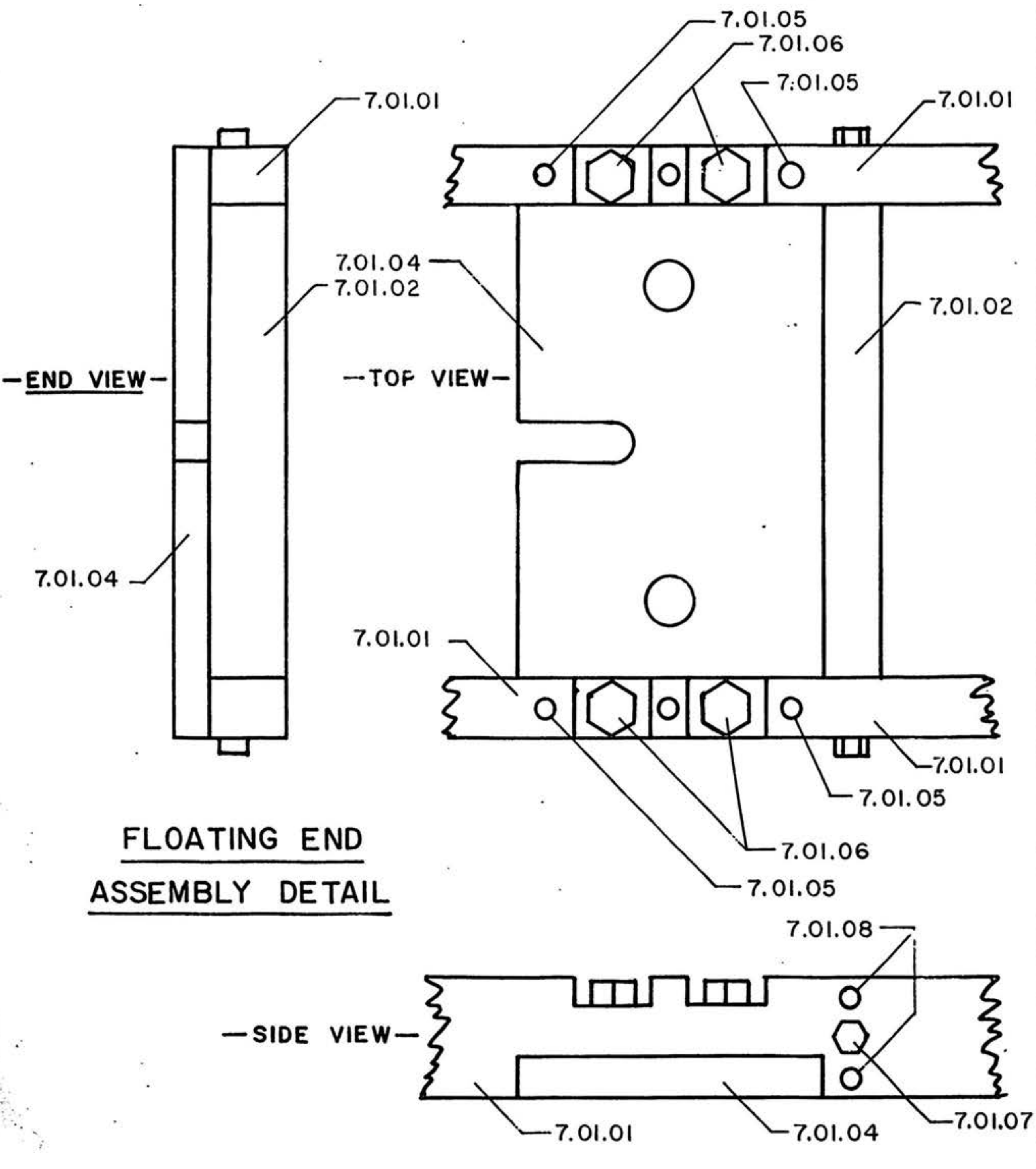
M.S.M. PHYSICS DEPT.
VACUUM SPECTROGRAPH

JKH 6/28/57	PLATFORM FRAME ASS'Y.
	7.01.00.B



SEE NOTES 1&2 ON DWG. 7.01.01.B

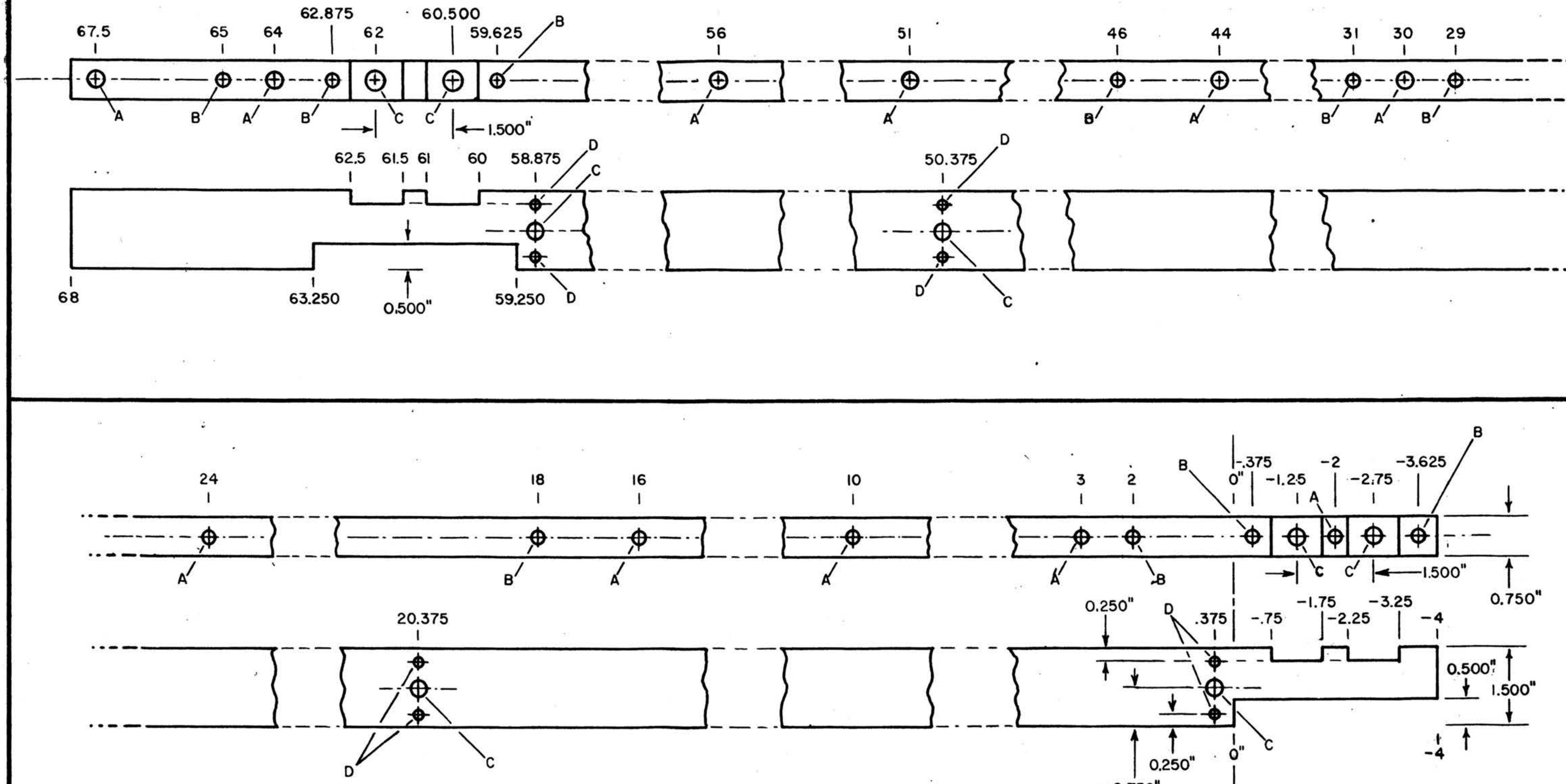
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 6/29/57	PLATFORM FRAME ASS'Y.
HALF SCALE DWG.	7.01.00.C



FLOATING END ASSEMBLY DETAIL

SEE NOTES 1 & 2 ON DWG. 7.01.00.B

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 6/29/57	PLATFORM FRAME ASS'Y.
HALF SCALE	7.01.00.D

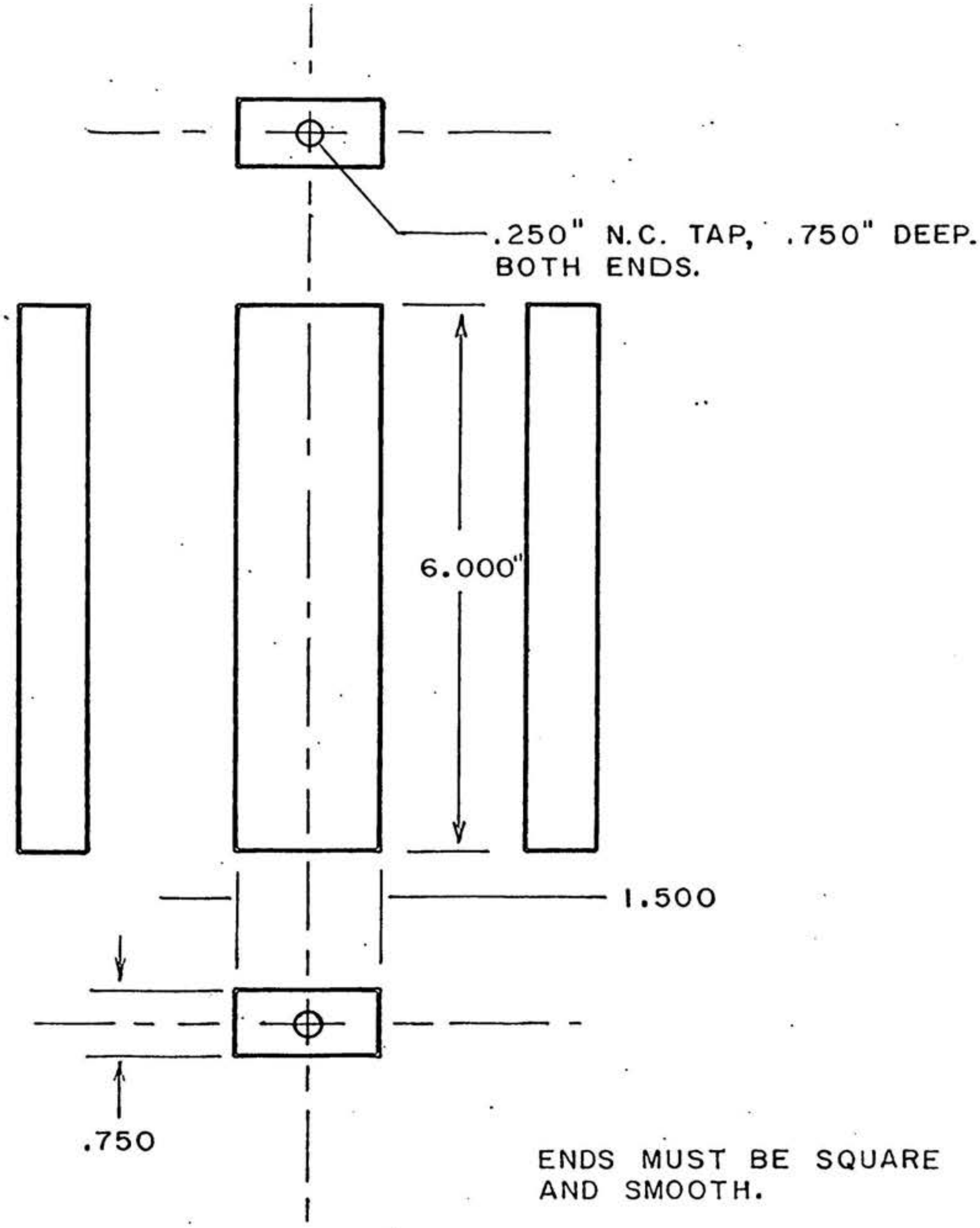


—GUIDE TO HOLES—
A - 1/4" NC TAP — 5/8" DEEP — 11 HOLES.
B - 1/4" DRILL HOLE — THRU — 10 HOLES.
C - 9/32" DRILL HOLE — THRU — 8 HOLES.
D - 3/16" DRILL HOLE — THRU — 8 HOLES.

MATERIAL — 0.750" x 1.500" x 72.000" 75S-T AL.
TOL. — ± .015" - ALL DIMENSIONS.

NOTES:
1. LONGITUDINAL DIMENSIONS ARE IN INCHES FROM FROM THE 0" REFERENCE LINE LOCATED FOUR INCHES TO THE LEFT OF THE RIGHT END. DIMENSIONS ARE POSITIVE TO THE LEFT OF ZERO AND NEGATIVE TO THE RIGHT OF ZERO.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
LONGITUDINAL MEMBER	JKH 1-23-58
7.01.01-2	HALF SCALE

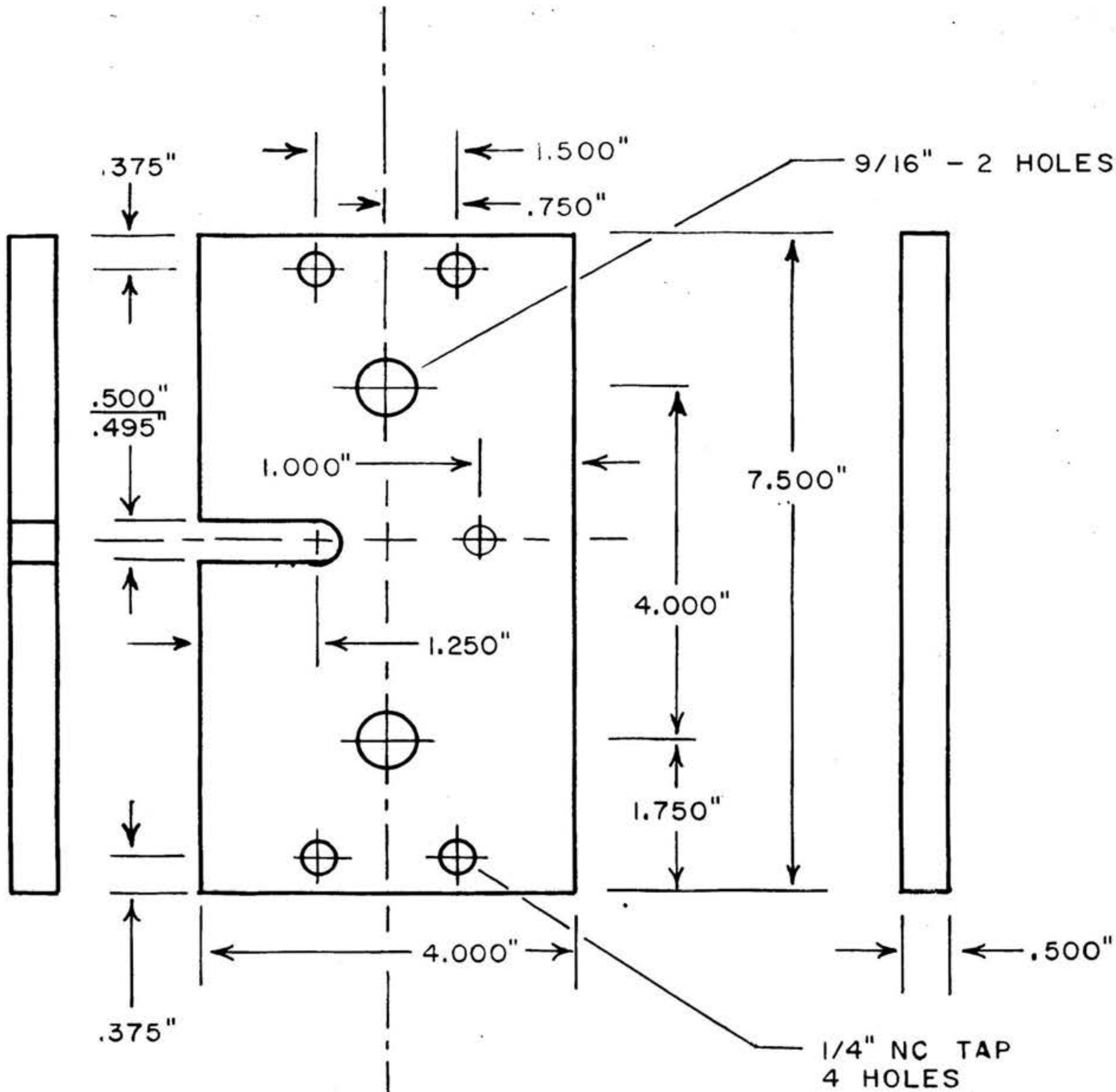


TOL: ± .015"
MATERIAL: 1.500" x .750" 75 ST AL. BAR

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

JKH 1/7/58	CROSS MEMBER
	7.01.02-4



NOTES: a. OMIT .500" CENTER SLOT ON PART No. 7.01.03.
b. OMIT 1/4" CENTER HOLE ON PART No. 7.01.04.

MATERIAL: .500" x 4.000" 75 ST AL. BAR
TOL: ± .015"

M.S.M. PHYSICS DEPT.	
VACUUM SECTROGRAPH	
JKH 1/8/58	MOUNTING PLATES
	7.01.03 — 7.01.04

Drawing 7.02.00-A
Grating End Mounting Platform
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

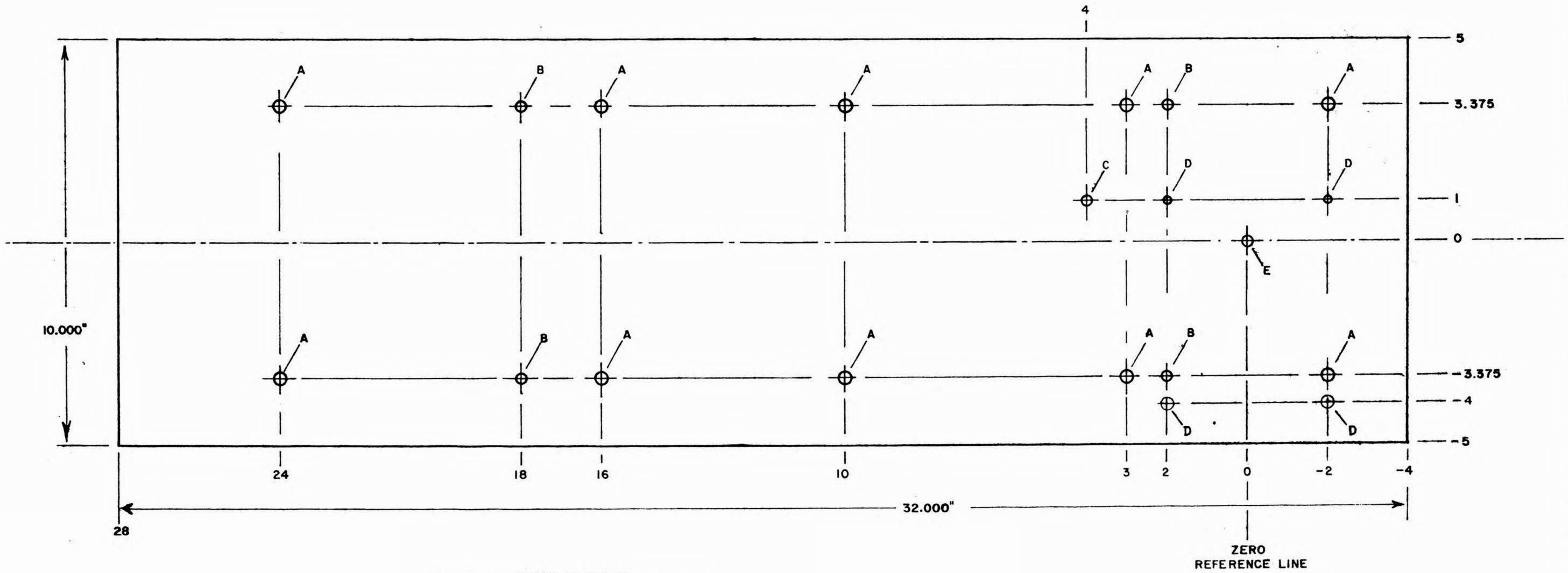
Part No:	Dwg. No:	Note:	Description
7.02.00	7.02.00-A	A	Grating End Mounting Platform
7.02.01	7.02.01		Mounting Plate
7.02.02S10	None		Screw, socket, 1", 1/4" N.C. brass or cad. plate steel
7.02.03S4	6.02.14		Pin (same as P/N 6.02.14)

ASSEMBLY NOTES:

(A)

The grating end mounting plate is bolted to the frame assembly (7.01.00) between station lines -4.000 and +28.000 with 7.02.02S10 screws. Alignment of the plate to the frame assembly is maintained by the use of four 7.02.03S4 alignment pins through 0.250" holes at station lines +2.000 and +18.000.

At initial assembly, the mounting plate is placed on the frame assembly in a position such that it is centered within 0.015" of the line between the center pin hole in plate 7.01.03 and the slot in plate 7.01.04. The plate is placed so that the 0.250" "E" hole center will be within 0.015" of the face plane of the grating end flange of the vacuum chamber when the platform is installed and index pin 7.01.10S1 is installed. This places the "E" hole center one inch from the center of the 7.01.10S1 pin hole in mounting plate 7.01.03.



GUIDE TO HOLES

A – 9/32" DRILL HOLE – 10 HOLES.
B – 1/4" HOLE – 4 HOLES – DRILL IN ASSEMBLY THRU B HOLES IN PARTS 7.01.01-2.
C – 1/4" HOLE – DRILL IN ASSEMBLY WITH PART 5.06.01.
D – 10-24 NC TAP – 4 HOLES.
E – 1/4" DRILL HOLE.

MATERIAL – 0.500" x 10.000" 75 S-T AL. BAR
TOL.- $\pm$.015"

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 1-30-58	MOUNTING PLATE
ONE-HALF SCALE	7.02.01

Drawing 7.03.00-A
Center Reference Platform
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
7.03.00	7.03.00-A	A	Center Reference Platform
7.03.01	7.03.01		Center Reference Plate
7.03.02	None		Screw, socket, 1", 1/4" N.C., brass or cad. plate steel
7.03.03	None		Pin, 1", 0.250" dia., steel
7.03.04	7.03.04	B	Center Reference Block
7.03.05	7.03.05		Ref. Arm Pivot
7.03.06	7.03.06		Ref. Arm Rod
7.03.07S2	None		Screw, hex, 1-1/4", 1/4" dia., N.C., brass
7.03.08S2	None		Nut, hex, 1/4" N.C., brass
7.03.09S1	None		Shaft, 3.750", 0.250", polished steel

ASSEMBLY NOTES:

(A)

The center reference plate is installed on the top side of the platform frame between station lines +28.000 and +32.000. It is attached to the frame by screws 7.03.02S2 at station line +30.000. Its location relative to the frame is maintained by alignment pins 7.03.03 at station lines +29.000 and +31.000.

ASSEMBLY NOTES (Cont'd)

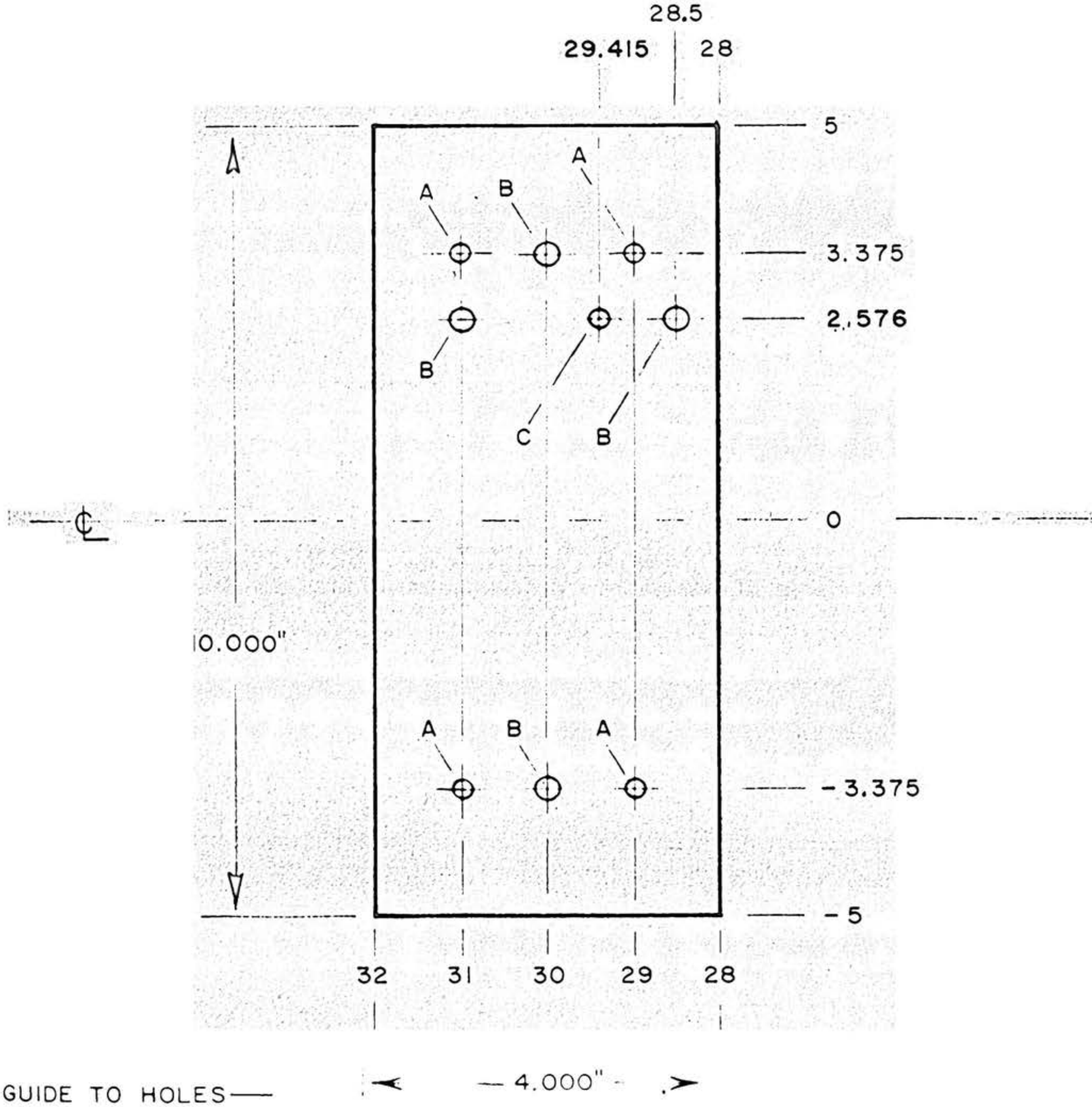
The plate is located so that the distance between the center of the "C" hole at (29.415, 2.576) and the center of the grating center hole at (0.000, 0.000) is 26.528" ±0.005". The hole down screws are then tightened and the four alignment holes are then drilled through the matching holes in frame members 7.01.01-2. Alignment pins 7.03.03S4 are then driven into place.

(B)

The center reference block is mounted on the center reference plate so that the 0.253" hole is in coincidence with the "C" hole in the plate. The "A" holes in part 7.03.04 are then drilled and the block is attached with screws 7.03.07 and nuts 7.03.08.

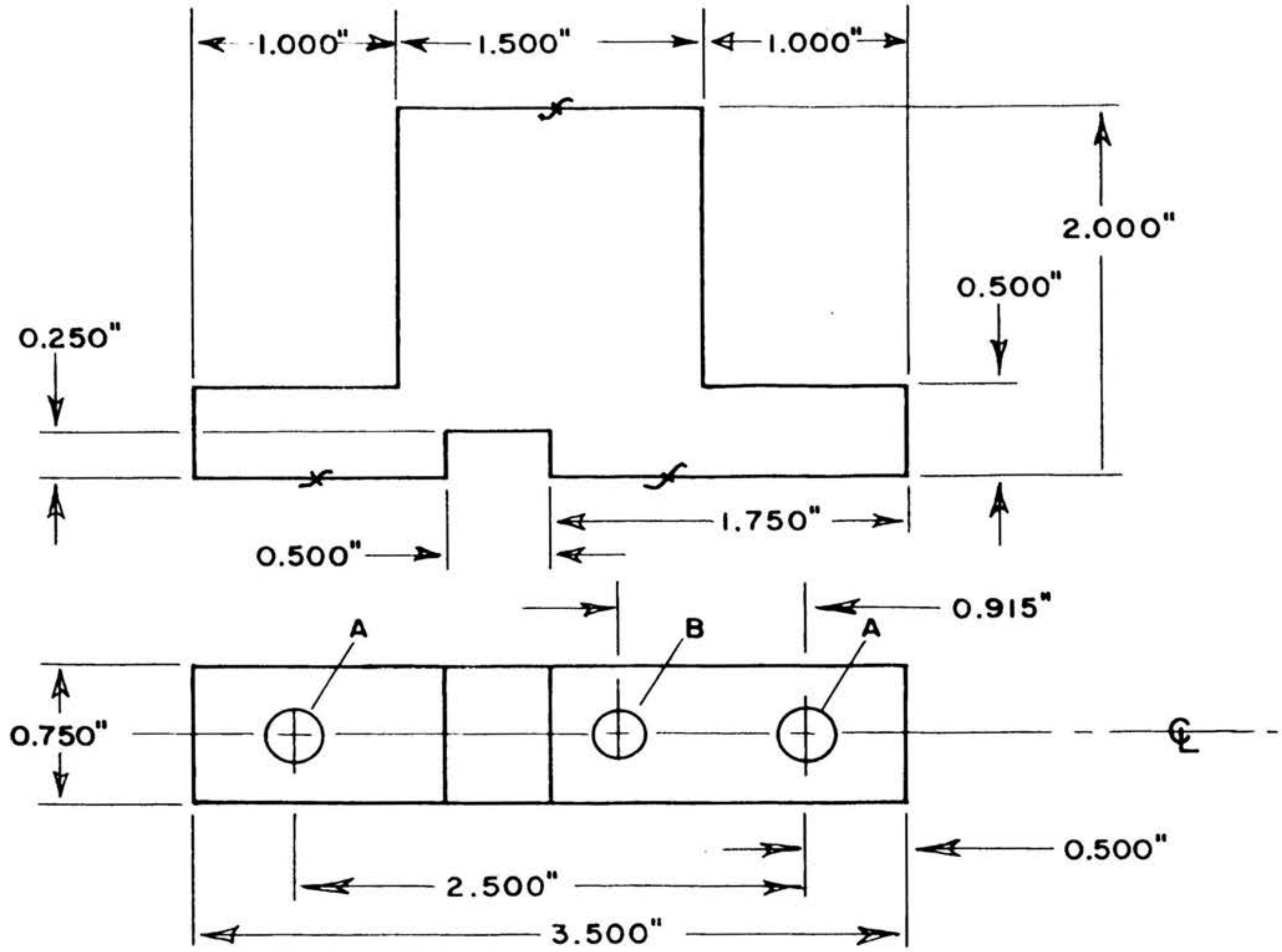
Reference arm pivot 7.03.05 is then placed on the block, the pivot shaft 7.03.09S1 installed in hole "A", and the reference arm rod 7.03.06 screwed into the "B" hole in the pivot block.

MATERIAL — 0.500" x 4.000" 75S-T AL. BAR.
TOLERANCE — ± 0.015"



—GUIDE TO HOLES—
A – 1/4" HOLE – 4 HOLES – DRILL IN ASSEMBLY THRU B HOLES IN 7.01.01-2.
B – 9/32" DRILL HOLE – 4 HOLES.
C – 1/4" HOLE – THRU – THIS HOLE IS THE ROWLAND CIRCLE CENTER REFERENCE.

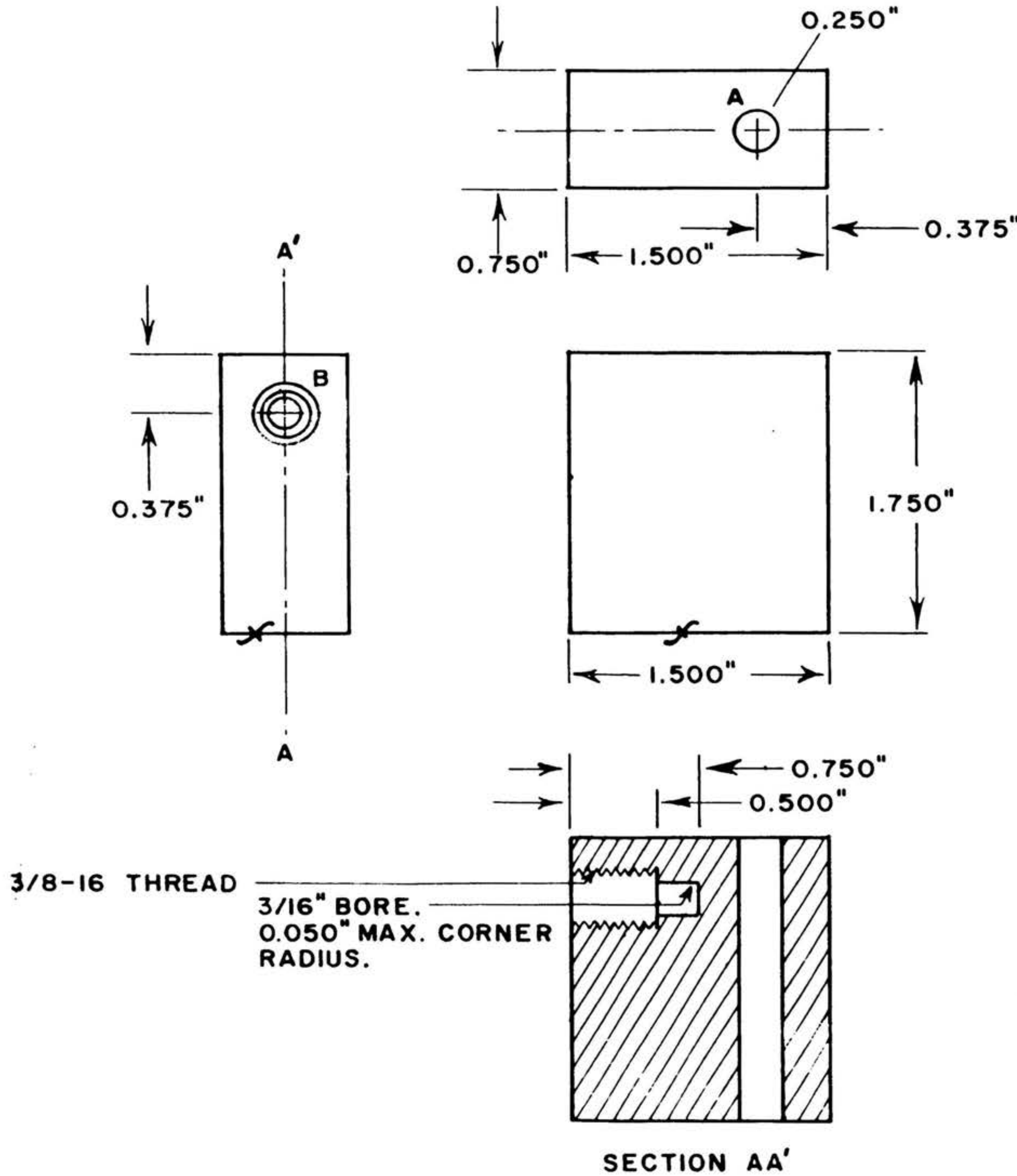
M.S.M. PHYSICS DEPARTMENT	
VACUUM SPECTROGRAPH	
JKH 1-31-58	CENTER REFERENCE PLATE
HALF SCALE	7.03.01



A - 9/32" HOLE — DRILL IN ASS'Y WITH 7.03.01.
B - 0.253" HOLE.

TOL - ± 0.015"
MAT. 7075 T6 BARE AL. PLATE

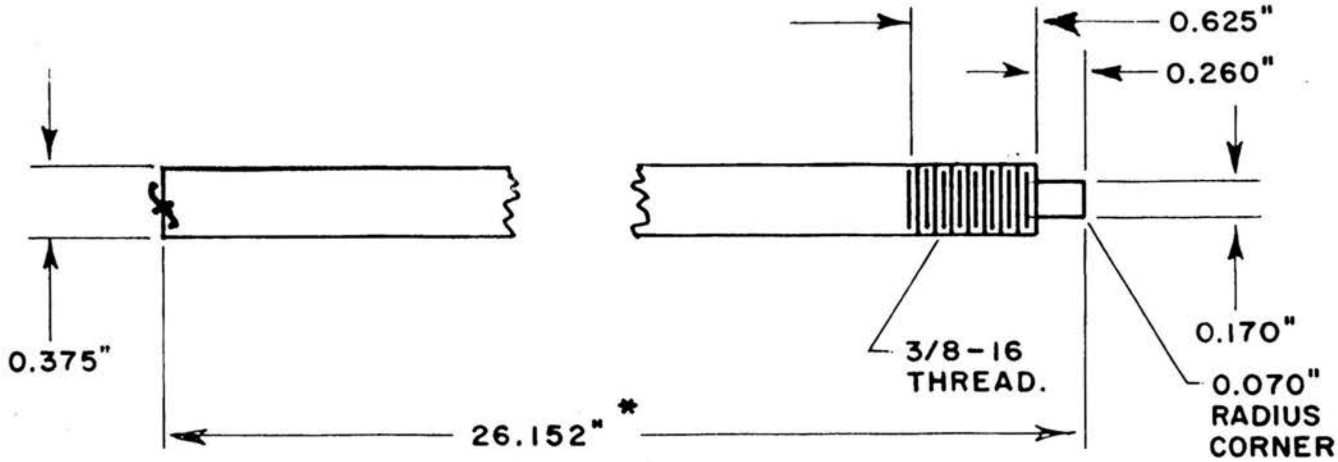
M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	CENTER REFERENCE BLOCK
	7.03.04



TOL - ±0.015"

MAT. 0.750" 7075 T4 AL.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	REFERENCE ARM PIVOT
	7.03.05



*LENGTH TO BE SUCH AS TO PLACE LEFT END 26.528" ± 0.005" FROM CENTER OF HOLE "A" IN 7.03.05 WHEN ROD IS SCREWED INTO HOLE "B".

TOL - ± 0.005"

MAT. - 7075 T6 AL — 3/8" ROD.

M. S. M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	REFERENCE ARM ROD
	7.03.06

Drawing 7.04.00-A Sheet 1 of 1

Detector End Mounting Platform
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
7.04.00	7.04.00-A	A	Detector End Mounting Platform
7.04.01	7.04.01		Mounting Plate
7.04.02S10	None		Screw, socket, 1", 1/2" N.C., brass or cad. plate steel
7.04.03S4	6.02.14		Pin, (same as 6.02.14)

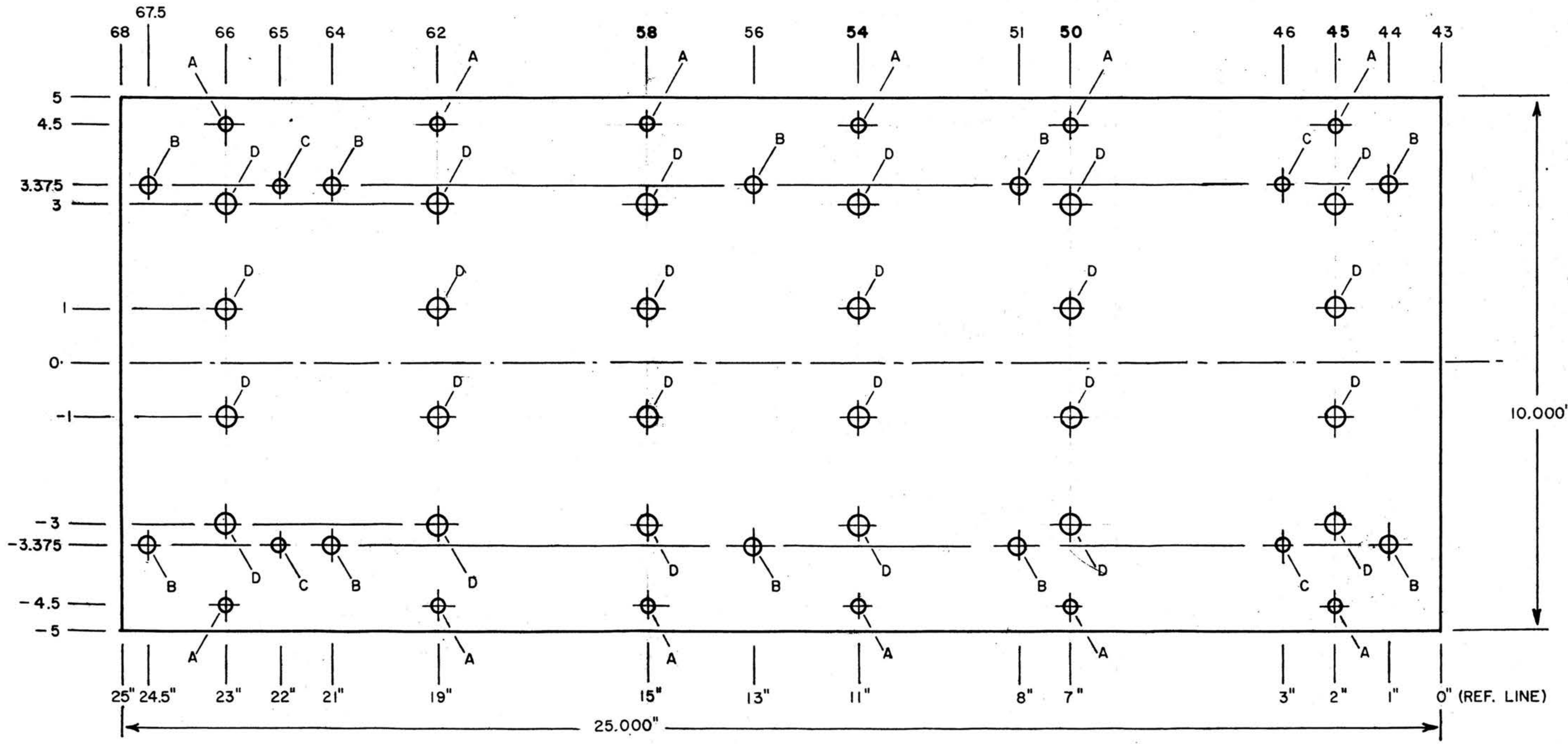
ASSEMBLY NOTES:

(A)

Mounting plate 7.04.01 is bolted in place on the frame assembly between station lines +43.000 and +68.000 with screws 7.04.02S10 at station lines +44.000, +51.000, +56.000, +64.000 and +67.500. Alignment is preserved by index pins 7.04.03S4 at station lines +46.000 and +65.000.

The mounting plate is placed in position and adjusted until it is centered within 0.015" of the spectrograph center line defined by the center reference hole in plate 7.01.03 and the slot in plate 7.01.04. The position along the frame is adjusted so that the line between the centers of the two "A" holes at station line +45.000 is 45.000" ±0.015" from the grating center reference hole in plate 7.02.01 at (0.000, 0.000). The holes for the index pins are then drilled through the matching holes in the frame assembly and the pins installed.

NOTE — STATION NUMBERS AT TOP OF DRAWING GIVE DISTANCE IN INCHES FROM GRATING CENTER.
POSITION NUMBERS AT END OF DRAWING GIVE DISTANCE IN INCHES FROM SPECTROGRAPH CENTER LINE.



— GUIDE TO HOLES —
A – 1/4" DRILL HOLE — THRU — 12 HOLES.
B – 9/32" DRILL HOLE — THRU — 10 HOLES.
C – 1/4" DRILL HOLE — THRU — 4 HOLES.
DRILL IN ASSEMBLY THRU B HOLES
IN PARTS 7.01.01-2.
D – 3/8" NC TAP — 24 HOLES.

MATERIAL – 0.500" x 10.000" 75S-T AL. BAR
TOL.– ±.015" – ALL DIMENSIONS.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 1-25-58	MOUNTING PLATE
HALF SCALE	7.04.01

8.00.00: VACUUM CHAMBER

8.01.00: Chamber Design Considerations

Inside pressures on the order of 10^{-5} to 10^{-6} mmHg are desirable for spectroscopy of the vacuum ultraviolet. Consequently, the vacuum chamber was required to be capable of pressures of this magnitude. This requirement made the use of high quality seals and first rate weld joints a matter of necessity. It was also desirable to utilize materials having good outgassing characteristics.

8.01.02: Mechanical Strength

A vacuum chamber capable of withstanding pressure differentials of one atmosphere without objectionable distortion of its physical dimensions was required. As the walls of the chamber were required to serve as alignment references, such distortion could not be tolerated.

8.01.03: Dimensions and Shape

The basic shape and size of the vacuum chamber was dictated by the normal incidence geometry. This geometry required that the film holder end of the chamber be approximately thirteen inches wide and six inches tall. The geometry required that the length of the main chamber be approximately six feet long. The grating size required that the light inlet line be approximately two inches in diameter.

The requirement that the instrument serve as either a normal or grazing incidence spectrograph called for a chamber large enough to accept a grazing incidence plate holder in the area between the grating mount and the normal incidence plate holder. Consequently, a chamber having approximately the same dimensions along its entire length was indicated.

8.01.04: Equipment Accessibility

Ready accessibility to all equipment mounted inside the vacuum chamber with a minimum of handling heavy plates or chambers was considered a design necessity.

8.02.00: Vacuum Chamber Description

8.02.01: Material

The vacuum chamber was made from a length of 14 inch O. D., 3/8 inch wall mild steel pipe with forged steel flanges electrically welded at the ends and at the side access ports. Although brass or stainless steel would have been a better material from the outgassing standpoint, cost ruled out these materials.

8.02.02: Main Chamber Dimensions and Shape

The main vacuum chamber is shown by drawings 8.02.00-B, C and D in the packet in the back of this document. This chamber is 68 inches long and has an inside diameter of 13.250 inches.

A two inch inside diameter line is welded in at a fifteen degree angle to allow the light from the normal incidence light source mounted at the end of this line to enter the instrument. Another two inch line is welded to the main tube at station line +4.500 to accommodate the grating drive shaft. A six inch flanged port welded to the bottom side of the chamber at station line +36.000 is designed to serve as a pump port. The diffusion pump mounts directly to this port.

Additional six inch access ports are provided on the side at stations +16.625 and +54.625. A six inch port is provided on the top at station +54.625 for the entry of such things as the film drive shaft, electrical, or vacuum lines. The port on the top at station +20.000 is used as an entry for vacuum gauges. Sufficient access ports are available to make it unnecessary to cut holes in the wall of the chamber for installation of new equipment. Standard 150 lb. bolt circle flanges are used on all flanges.

8.02.03: End Cap and Flanges

The normal incidence end of the chamber is closed by an 18.500 inch long end cap of the same material as the main chamber. This end cap (P/N 8.01.00) is shown by drawing 8.01.00-B in the packet in the back cover of this document. This deep end cap provides space inside the vacuum chamber for mounting equipment behind the normal incidence focal circle line. Removal of this cap provides direct access to the film positioner and film holder.

The grating end of the main chamber is closed by a standard 150 lb. flange cover plate that has been ground to a 40 micro-inch surface finish in order to allow a good seal to the "O" ring gaskets used between the flange and cover plate.

Similarly prepared flange plates are used to close the other openings in the chamber.

A two inch high vacuum gate valve (8.03.05S1) is used between the light source line flange and the light source to allow isolation of the main chamber from the light source.

8.02.04: Seals and High Vacuum Precautions

Careful attention was paid to the problem of obtaining good vacuum seals and minimization of outgassing of the vacuum system.

Shielded arc electric welding was used in welding the vacuum chamber walls in order to minimize the risk of leaks in the welded seams. The entire vacuum chamber was then assembled and thoroughly leak tested in the builder's shop. All leaks were repaired using shielded arc welding equipment. All flange surfaces and "O" ring grooves were carefully inspected, leak tested and reworked as required in the shop. These precautions resulted in a vacuum chamber that gave all the appearances of being entirely leak free when installed in the laboratory.

The inside walls of the vacuum chamber were buffed bright using a power driven wire brush in order to remove any rust that would be likely to outgas.

All of the vacuum system flange surfaces and "O" ring grooves were ground to a 40 micro-inch surface finish in order to provide acceptable surfaces for the "O" ring seals.

Double "O" ring seals were used for the large end openings and suitable "O" ring grooves were ground into the main chamber flange surfaces. "O" ring gaskets 8.03.03S2 and 8.03.04S2 are used in these grooves. The smaller flanges were ground smooth, and self centering, double ring high vacuum seals (8.03.07S2 & 8.03.08S4) made by the Vacuum Research Company of San Francisco, California, were used.

8.02.05: Mounting Platform Supports

The mounting platform is supported at each end of the vacuum chamber by supports 8.02.06 and 8.02.07 spot welded to the inside of the chamber as shown in drawing 8.02.00-H. These supports are accurately leveled and positioned in accordance with drawing 8.02.00-A in order to provide dependable reference points for the spectrograph internal equipment.

8.03.00: Vacuum Chamber Installation

8.03.01: Main Chamber Installation

The main vacuum chamber is mounted on support stand 9.01.00 and chamber supports 8.02.04-2 are bolted to the stand mounting pads using the 8.03.13S8 Bolts and 8.03.14S8 nuts. The six inch flanges are installed using the 8.03.08S4 seals and the 8.03.11S40 bolts and 8.03.12S40 nuts. After installation, the support block surfaces are leveled by turning the stand leveling screws.

8.03.02: End Cap Installation

The end cap (8.01.00) is supported by three rods suspended from the overhead track assembly (9.02.00). The rods are hooked into the two hooks installed in the flange edge and to the steel band around the back side of the cap. The rod lengths are then adjusted to the proper length to yield proper mating of the cap to the main chamber. "O" ring seals 8.03.03S2 and 8.03.04S2 are installed in the grooves, and the cap is bolted in place using bolts 8.03.15S24 and nuts 8.03.16S24.

8.03.03: End Plate Installation

The 21 inch end plate (8.03.10S1) is suspended from the two rods provided by the overhead track. "O" ring seals 8.03.03S2 and 8.03.04S2, bolts 8.03.15S24 and nuts 8.03.16S24 are used to seal and hold the plate in place.

8.04.00: Vacuum Chamber Construction

All detailed information required for the construction of the vacuum chamber is given by the series 8.00.00 drawings. See drawing 8.00.00-A. The larger drawings of this series are located in the packet in the back cover of this document.

Drawing 8.00.00-A
Vacuum Chamber
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y No:	Dwg. No:	Note:	Description:
8.00.00	8.00.00-A		Vacuum Chamber
8.01.00	8.01.00-A		End Cap
8.02.00	8.02.00-A		Main Vacuum Chamber
8.03.00	8.03.00-A		Hardware & Seals

Drawing 8.01.00-A

End Cap
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
8.01.00	8.01.00-A 8.01.00-B	A	End Cap
8.01.01S2	None	B	Hook, 3/8", N.C. thread, steel
8.01.02S1	None	C	Band, 1/16" iron plumber strap
8.01.03S1	None		Flange, 14"
8.01.04S1	None		Tube, 7.062" long, 14" O.D., 3/8" wall, ATSM spec A-53 seamless mild steel
8.01.05S1	None		Welding Cap, 14" O.D., 3/8" wall, mild steel

ASSEMBLY NOTES:

(A)

Machine and assemble end cap as indicated in dwg. 8.01.00-B. Protect flange surface during shipment and handling with soft wood cover. Buff inside of cap bright with steel brush.

(B)

Tap two 3/4 inch deep holes with 3/8 inch tap and screw in threaded hooks (8.01.01S2) at center of flange edge at points two inches each side of the center at the top side.

(C)

Bend the iron plumbers strap (8.01.02S1) around the end of the end cap just aft of the point where the cap bell is welded to the straight portion of the cap tube. Drill 1/2 inch holes in the ends of the strap to receive the hanger hook. Secure strap with bolt.

Drawing 8.02.00-A
Main Vacuum Chamber
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
8.02.00	8.02.00-A 8.02.00-B 8.02.00-C 8.02.00-D 8.02.00-H 8.02.00-I	A	Main Vacuum Chamber Ass'y View, Side Ass'y View, Top Ass'y View, Rt. End Support Block Location Grating Drive Line Details
8.02.01S2	8.02.01		Flange, 2 inch
8.02.01S5	8.02.02		Flange, 6 inch
8.02.03S1	None		Main Tube 58.125" long, 14" O.D., 3/8" wall, ATSM spec. A-53 seamless mild steel. Machined as per dwgs. 8.02.00-B, C, D & I
8.02.04-2	8.02.04		Support
8.02.05S2	8.02.05		Flange, 14 inch
8.02.06	8.02.06 8.02.07	B	Support Block-Grating End
8.02.07	8.02.06 8.02.07	B	Support Block-Detector End
8.02.08S1	None		Line, light source, 2" I.D., mild steel pipe, 150 lb.
8.02.09S1	None		Line, grating drive, 2" I.D., mild steel pipe, 150 lb.
8.02.10S1	None		Pin, 2", 0.500" dia., polished steel

ASSEMBLY NOTES:

(A)

Assemble the chamber in accordance with drawings 8.02.00-B, C, D, H & I and assembly flag notes 1 through 23. These notes correspond to the numbered flags on the assembly drawings.

General Assembly Notes;

I. All flanges have standard 150 lb. bolt circle and drilling. All facings are to be smooth faced except where otherwise noted.

II. All welds must be made with an inert gas shielded arc welding process. Welds must be leak free to inside pressures of 10^{-6} mmHg.

III. All flanges are to be oriented as indicated.

IV. The inside diameters must be free of obstruction except for support blocks 8.02.06 & 8.02.07.

V. All flanges are to be free of scratches and are to be protected with wood protectors during shipment.

Assembly Notes - Flag Numbers

1. Arc welded joint. Use standard non-reinforced nozzle weld. CAUTION: Weld must be suitable for high vacuum. See note II.

2. See dwg. 8.02.01 for detailed flange specifications. Note orientation of bolt holes indicated in dwg. 8.02.00-D.

3. 4. Six inch modified welding neck flange. See dwg. 8.02.02, for detailed flange specifications and instructions for modification of standard welding neck flanges.

5. Arc welded joint. Use inert gas shielded arc weld. Use standard 90° nozzle weld (non-reinforced).

6. Two inch modified welding neck flange. See dwg. 8.02.01 for detailed flange specifications and dwg. 8.02.00-I for cross section view through plane AA^1.

Assembly Notes - Flag Numbers (Cont'd)

7. Welded steel support (part 8.02.04-2) welded to tube. See dwg. 8.02.04.

8. Flange is modified Crane type 578, 14" welding neck flange welded to main tube. This flange has special facing as per dwg. 8.02.05.

9. See note 3.

10. In order to show this assembly to this scale, the right end view is shown on dwg. 8.02.00D. To obtain a full three view dwg., place the dwgs. in accordance with section 2.00.00.

11. Point of intersection of light source line, center line and outside wall line of the main tube. This point is located and dimensioned on this drawing only as an aid in boring the hole for the 15° line. The tolerance indicated is not intended as a tolerance for the final assembly.

12. The dotted lines indicate the location of the light source line on the back side of the tube.

13. Center of light source flange face. The position of this flange is critical! The indicated tolerance must be met!

14. Heavy line indicates weld. See note II.

15. Location of chamber support (8.02.04) on bottom side.

16. See note 3.

17. Heavy line indicates butt welded seam. The 14" flanges are butt welded to the main tube. This weld is to be done with an inert gas shielded arc. Flange is modified welding neck flange. See dwg. 8.02.05. Main tube is 14" O.D., ASTM spec. A-53 seamless steel pipe.

18. Center line of two inch flanged line on front side of chamber. Note that this center line is two inches below the main chamber center plane (plane BB^1). See dwg. 8.02.00-I for cross section through plane AA^1.

Assembly Notes - Flag Numbers (Con't'd)

19. Two "O" ring grooves are turned into the flange face. See dwg. 8.02.05 for flange specifications and cross section through plane BB^1.

20. The 1/2 degree tolerance applies to the angle between the support and the two inch linementioned in note 18.

21. The 1/4 degree tolerance applies to the angle between the support and the two inch light source line set at an angle of 15 degrees with the main chamber center line. See dwg. 8.02.00-B.

22. Light source line flange (back·side). See dwg. 8.02.01 for flange details.

23. Welded steel support (8.02.04-2) welded to tube. See dwg. 8.02.04 for support details. Heavy line indicates weld.

(B)

Support blocks 8.02.06 and 8.02.07 are welded in near the ends of the main chamber as indicated in dwg. 8.02.00-H. Part 8.02.06 is located between stations 0.000 & -4.000. Part 8.02.07 is located between stations +59.250 & +63.250. Top surfaces of both blocks are at W.L. -5.375.

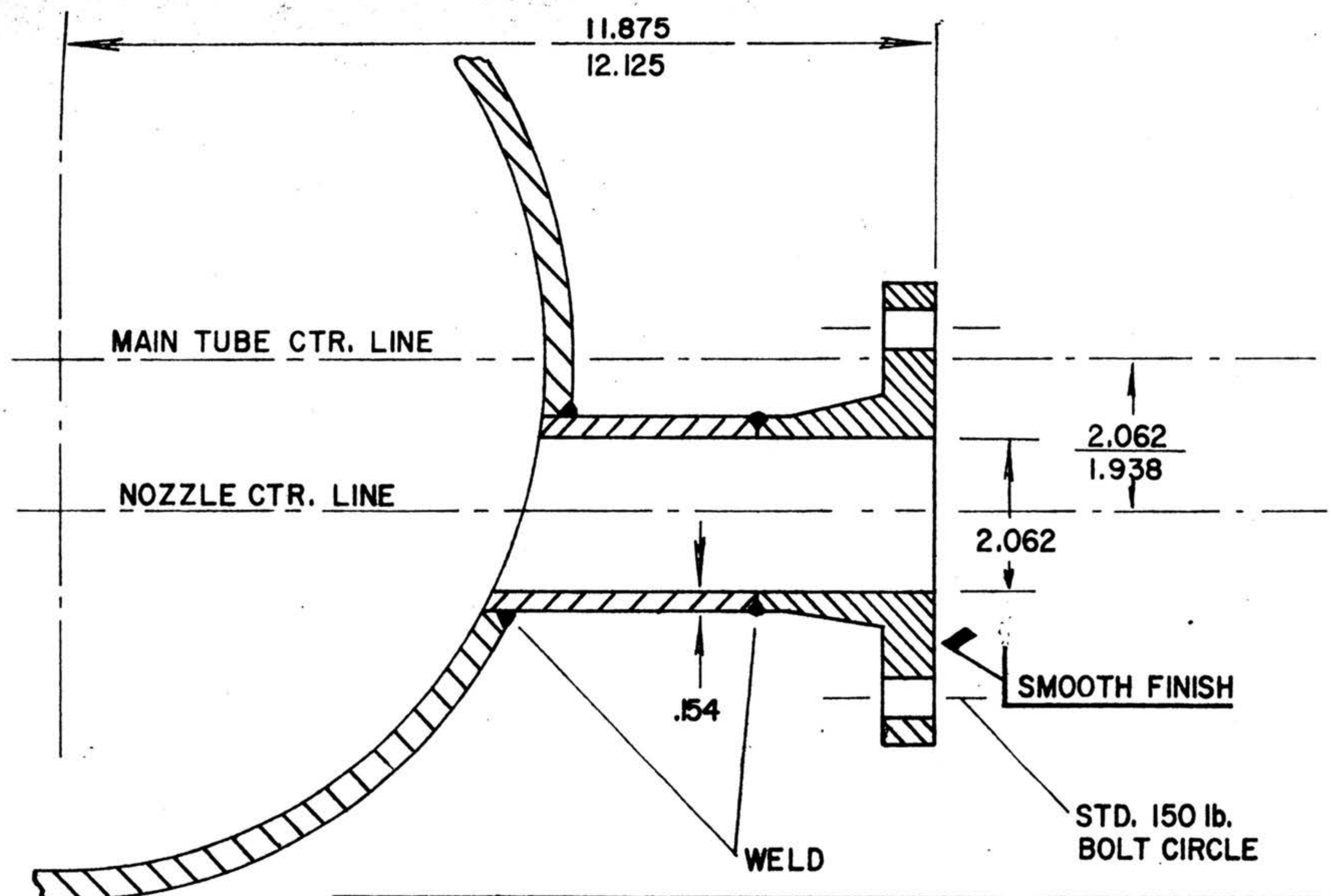
These blocks must be aligned relative to each other so that the center of the top mounting surfaces of part 8.02.07 is within ±0.015" of the plane defined by the top surface of part 8.02.06. In order to prevent forced bowing of the mounting platform beyond the allowable ±0.015", the blocks must be aligned so that the angle between the planes of their top surfaces is no more than <u>1.5 min. of arc</u>. Allowable platform warpage dictates that the angle between the surface planes about the common axis through the centers of their top surfaces be no more than <u>3.0 min. of arc</u>.

Block 8.02.06 is the primary reference and block 8.02.07 is aligned in relation to it. Alignment of 8.02.06 is slightly more critical than 8.02.07. The station -4.000 edge of 8.02.06 is located 0.375" ±0.015" from the surface of the grating end flange surface. The center of 8.02.06 is to be located at position line 0.000 ±0.025". Position line 0.000 is any line in the vertical plane that contains the main chamber center line and is perpendicular to the horizontal plane containing the main chamber center line

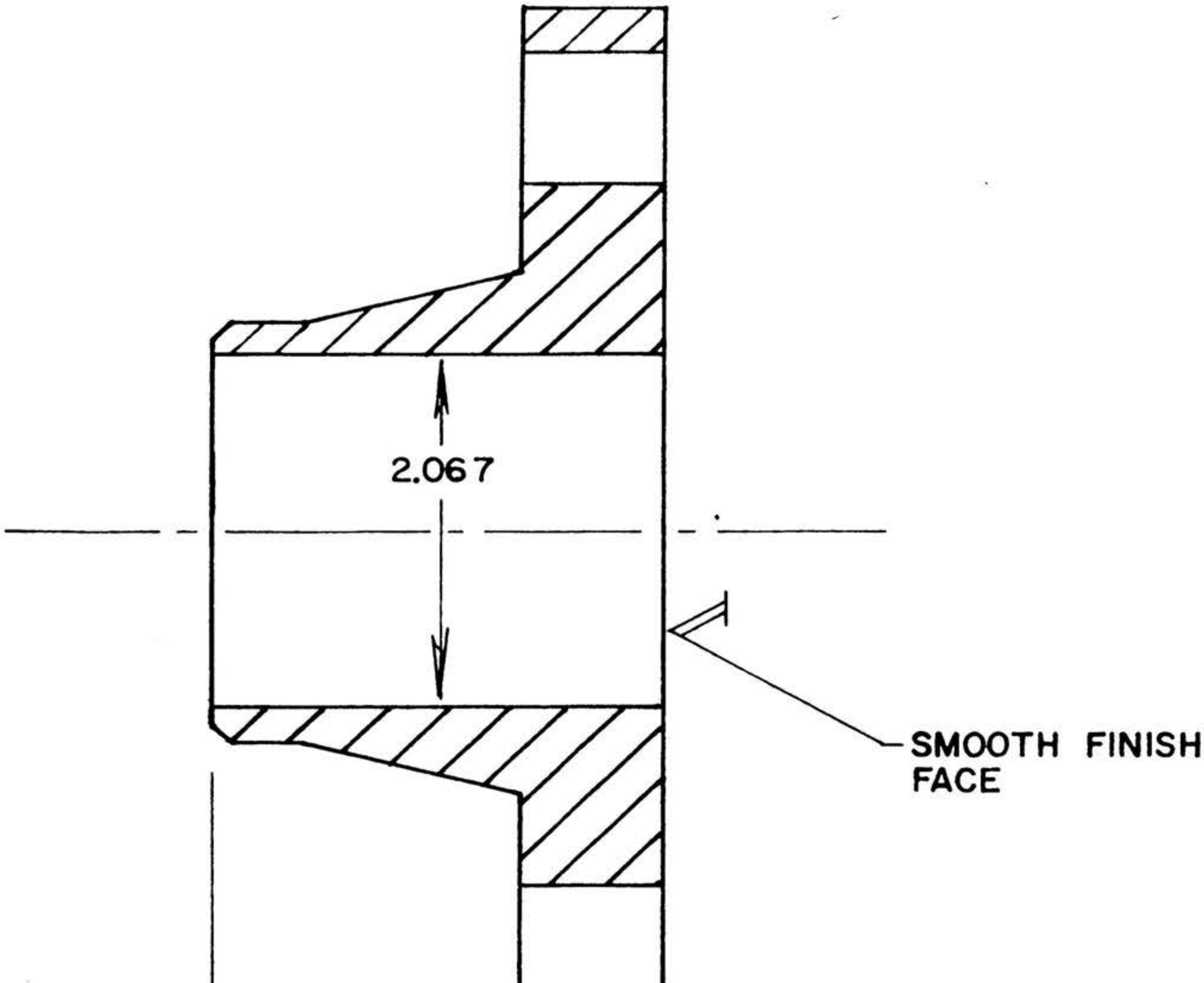
ASSEMBLY NOTES (Cont'd):

and the center line of the 2" pipe entering the main chamber at station 26.080. The center of the top surface of 8.02.06 is located at WL -5.275 which is 5.375" ±0.025" below the horizontal plane containing the center lines of the main chamber and the 2" pipe entering the main chamber at station 26.080. Angular displacement between the 8.02.06 top surface and this plane about a longitudinal axis must be zero ±3.0 min. of arc. Angular displacement between the top surface and this plane about a lateral axis must be zero ±1.5 min. of arc.

The nominal location for the center of block 8.02.07 is at station line 61.250. The block must be positioned so that the distances between the "D" holes in part 8.02.07 and the corresponding "D" holes in part 8.02.06 are 63.250" ±0.015". The lateral center of the block must be positioned vertically so that the center of its top surface will be within 0.015" of the plane defined by the top surface of part 8.02.06. The center of the top surface also must be positioned vertically so that it is 5.375" ±0.025" below the horizontal plane containing the center lines of the main chamber and the 2" pipe entering the main chamber at station line 26.080. The angle between the top surface of 8.02.07 and that of 8.02.06 about the common longitudinal axis through the centers of their top surfaces is zero ±3 min. of arc. The angle between the top surface plane and that of the 8.02.06 top surface plane about a lateral axis is zero ±1.5 min. of arc.



NOZZLE - 2 in. J.K.H 4/6/56 REV. 2	M.S.M. PHYSICS DEPT. VACUUM SPECTROGRAPH DWG. 8.02.00-I

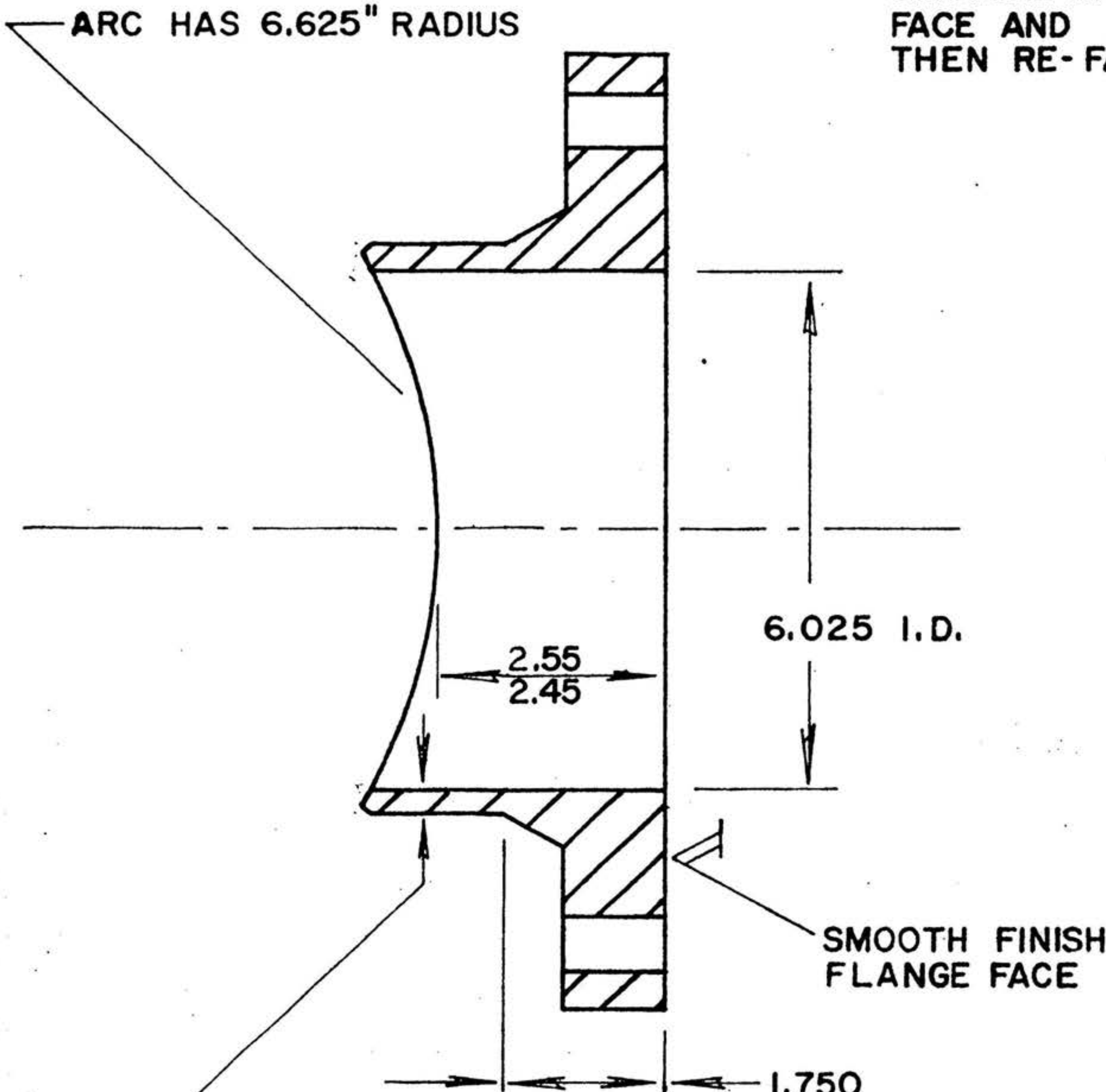


REFACE STD. 2" WELDING NECK FLANGE AS SHOWN BY RE-MOVING ORIGINAL RAISED SURFACE.

2 REQUIRED

2" FLANGE FULL SCALE 4/6/56 REV. 2	M.S.M. PHYSICS DEPT. VACUUM SPECTROGRAPH DWG. 8.02.01

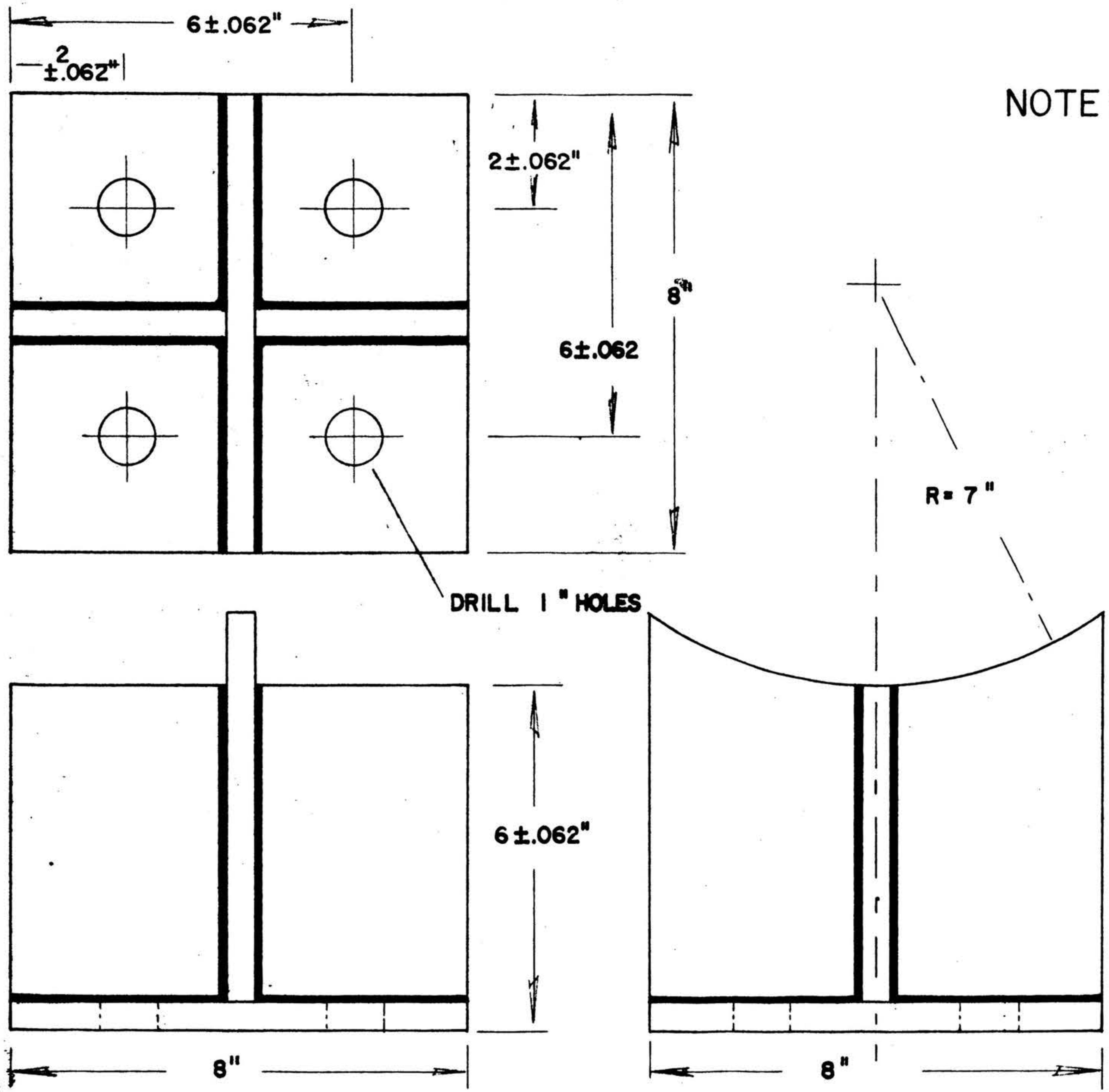
NOTE: REMOVE ORIGINAL RAISED FACE AND THEN RE-FACE



REMOVE ORIGINAL TAPER TO GIVE SAME O.D. AS O.D. AT [redacted] EDGE OF BEVEL.

MODIFY STD. 6", 150 lb. FLANGE AS INDICATED.

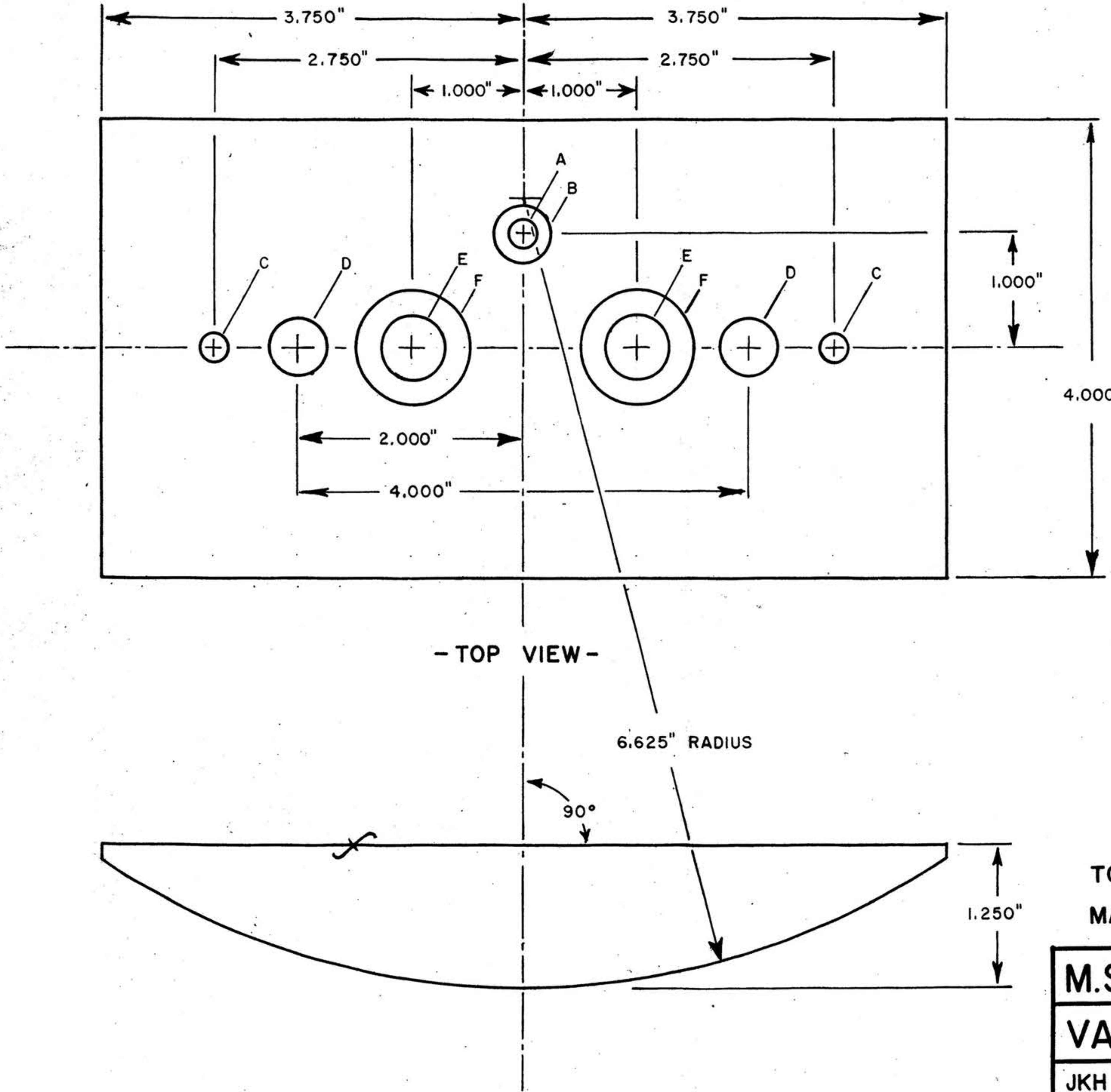
6" FLANGE 1/2 SCALE REV. 2	M.S.M. PHYSICS DEPT. VACUUM SPECTROGRAPH DWG. 8.02.02



NOTE: HEAVY LINE INDICATES WELD

2 SUPPORTS REQUIRED

MATERIAL-1/2" STEEL 1/2 SCALE
M.S.M. PHYSICS DEPT. VACUUM SPECTROGRAPH PART 8.02.04 - SUPPORT
DWG. 8.02.04



— GUIDE TO HOLES —

A — 0.250" HOLE, 0.500" DEEP. (PART 8.02.06 ONLY.) THIS HOLE IS DRILLED IN ASSEMBLY THROUGH MATCHING HOLE IN PART 7.01.03.

B — 0.500" HOLE, 1.000" DEEP. (PART 8.02.07 ONLY.) INSERT 0.500" PIN (PART 8.02.10).

C — 0.250" HOLES, THRU. TWO HOLES.

D — 1/2" NC TAP, THRU. TWO HOLES.

E — 9/16" HOLES, THRU. TWO HOLES.

F — 1" COUNTERBORE, 9/16" DEEP.

TOL. = ± 0.015"

MATERIAL = 1.250" x 4.000" MILD STEEL BAR

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 2/27/58	SUPPORT BLOCKS
GRATING END - 8.02.06	DETECTOR END - 8.02.07

Drawing 8.03.00-A
Hardware and Seals
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
8.03.00	8.03.00-A		Hardware & vacuum seals
8.03.01S8	None		Cap screw, 2-1/2", 5/8" dia. N.C., steel
8.03.02S8	None		Nut, hex, 5/8" N.C., steel
8.03.03S2	None		"O" ring gasket, 14" I.D., Goshen Rubber Co. GRC-27-84
8.03.04S2	None		"O" ring gasket, 15.5" I.D., Goshen Rubber Co. GRC-27-87
8.03.05S1	None		Valve, 2" gate, Vacuum Research Co.* VG-102
8.03.06	None		Not used
8.03.07S2	None		2" Vacuum Gasket, Vacuum Research Co.* G-102
8.03.08S4	None		6" Vacuum Gasket, Vacuum Research Co.* G-106
8.03.09S3	None		6", 150 lb steel flange, one side ground flat to 40 micro-inch surface finish

*420 Market Street
San Francisco, Calif.

Drawing 8.03.00-A

PART AND DRAWING LIST: (Cont'd)

Part No:	Dwg. No:	Note:	Description:
8.03.10S1	None		14", 150 lb. steel flange, one side ground flat to 40 micro-inch surface finish. Modify by installing two 3/8" hooks in the center of the top edge at points 2 inches to either side of the center.
8.03.11S40	None		Bolt, hex, 3-1/4", 3/4" dia. N.C., steel
8.03.12S40	None		Nut, hex, 3/4" N.C., steel
8.03.13S8	None		Bolt, hex, 1-3/4", 3/4" dia. N.C., steel
8.03.14S8	None		Nut, hex, 3/4" N.C., steel
8.03.15S24	None		Bolt, hex, 4-1/4", 1" dia. N.C., steel
8.03.16S24	None		Nut, hex, 1" N.C., steel

9.00.00: MOUNTING STANDS

9.01.00: Design Considerations

9.01.01: Vacuum Chamber Support

It was considered desirable to support the main vacuum chamber at a convenient height to allow work inside the chamber to be accomplished from a standing position. Experiment using a crude mock-up indicated that a center line elevation of fifty-two inches above floor level was optimum.

The stand was required to be sufficiently strong to support a load of one thousand pounds without objectionable distortion of its physical dimensions. Provisions for support of the normal incidence light source in a fixed position relative to the main chamber was required.

Adequate space for the main vacuum pumps beneath the chamber was also desired.

9.01.02: Overhead Support

Because the weight of the main vacuum chamber end cap and flange is more than can be conveniently handled, it was considered desirable to construct some sort of overhead track for handling these parts. A trolley or trolleys for moving these parts into and out of place was desired.

9.02.00: Main Chamber Mounting Stand Description

In order to satisfy the strength and regidity requirements, a main chamber mounting stand (Ass'y, No. 9.01.00) was made of two and three inch steel pipe welded into a rigid assembly. This stand is shown in figure 4.04.01-B with the vacuum chamber mounted on it.

The main chamber supports bolt to two matching support plates at the top of the structure. Two plates and a brace tie block are provided on the light source side of the stand for mounting the normal incidence light source supporting structure. Mounting the light source rigidly to the stand in this manner helps to keep the light source and entrance slits properly positioned. Dimensions of the stand and location of the light source mounting points are shown by dwg. 9.01.00-B.

Four leveling screws are provided in the base of the stand as an aid in leveling the spectrograph.

9.03.00: Overhead Track Description

The vacuum chamber end cap and the large end flange are supported by an overhead track and stand (Ass'y. No. 9.02.00). This assembly consists of a fifteen and one-half feet long, four inch steel "I" beam assembly (9.02.02) supported at an elevation of eighty inches by leg assemblies 9.02.01-2 made of lengths of two inch pipe. The assembled stand is shown by drawing 9.02.00-B.

The beam assembly has two five foot long sections of barn door track welded to each end. Barn door trolleys (9.02.05S2) mounted on these tracks carry the vacuum chamber end cap and end flange. Attached to these trolleys are metal plates 9.02.06 and 9.02.07 which support five rods (9.02.08-5) that hook into the hooks at the top of the vacuum chamber end cap and end flange. The length of these rods is adjustable to allow correct positioning of the load.

9.04.00: Overhead Track Installation

The overhead track assembly is placed directly over and parallel to the spectrograph center line. It is centered longitudinally so that when the end cap and end plate are bolted in place, both of the trolleys will be near the inside ends of their tracks.

9.05.00: Stand Construction

All necessary information for the construction of stand 9.01.00 is given by drawings 9.01.00-A and 9.01.00-B. Construction information for the overhead track is given by drawings 9.02.00-A and 9.02.00-B. Because of their large size, drawings 9.01.00-B and 9.02.00-B are located in the packet inside the back cover of this document.

Drawing 9.00.00-A
Support Stands
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y No:	Dwg. No:	Note:	Description:
9.00.00	9.00.00-A		Vacuum Chamber Support Stand and Overhead Track Assemblies Stand
9.01.00	9.01.00-A		Stand
9.02.00	9.02.00-A		Overhead Track Ass'y.

Drawing 9.01.00-A

Stand
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
9.01.00	9.01.00-A 9.01.00-B	A	Overhead Track Assembled View

ASSEMBLY NOTES:

(A)

Assemble stand as indicated in drawing 9.01.00-B. Weld all joints. Caution should be observed to insure that the completed stand will set flatly on the floor and that the top surfaces of the vacuum chamber mounting plates are in the same place.

Paint entire stand assembly with machine grey enamel.

Drawing 9.02.00-A
Overhead Track
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
9.02.00	9.02.00-A 9.02.00-B	A	Overhead Track Ass'y. Ass'y. View
9.02.01	9.02.00-B	B	Leg Assembly
9.02.02	9.02.00-B	C	Beam Assembly
9.02.03-2	9.02.00-B		Brace
9.02.04S8	None		Bolt, hex, 2-1/2", 5/8" N.C., steel
9.02.05S2	None		Trolley-Barn door type to match track on part 9.02.02
9.02.06	None		Trolley Plate (Flange Carrier), 1/2" steel plate. Drill as required.
9.02.07	None		Trolley Plate, (Cap Carrier), 1/2" steel plate. Drill as required
9.02.08S5	None		1/2" iron rod, thread on one end and bend hook in other end
9.02.09S5	None		Nut, 1/2" N.C., square
9.02.10S8	None		Nut, 5/8" N.C., hex, steel

ASSEMBLY NOTES:

(A)

Assemble track assembly as shown in dwg. 9.02.00-B. Bolt together with bolts 9.02.04S8 and nuts 9.02.10S8. Paint entire stand assembly with machine grey enamel.

Mount trolleys 9.02.05S2 in track and install trolley plates and support rods 9.02.09S5.

(B)

Assemble legs as indicated in dwg. 9.02.00-B.

(C)

Assemble beam ass'y. as indicated in dwg. 9.02.00-B.

10.00.00: GRAZING INCIDENCE CONVERSION

10.01.00: Grazing Incidence Conversion Capability

Although lack of time prevented completion of the grazing incidence portion of the instrument, provisions for easy conversion to grazing incidence were built into the existing instrument. In fact, all of the necessary hardware except a grazing incidence light source adapter was either constructed or already available for the arrangement described in section 4.03.04. Some additional hardware would be required to use the arrangement described in section 4.03.03. Such additional hardware would consist primarily of a mounting platform extension and a second end cap. (The existing end cap can not be used because the mounting platform extends beyond the end of the vacuum chamber at the N-I detector end.) This difficulty could be overcome by construction of a separate grazing incidence mounting platform that would extend from the grating mount end to support the grazing incidence plate holder. The construction of such a platform should not be a difficult task and would be desirable in many respects. A third possible grazing incidence arrangement could be utilized by moving the grating mount to the opposite end of the chamber and mounting the light source in the side port used for normal incidence plate holder access. The plate holder would be located on a platform extension into the end cap.

Each of the grazing incidence arrangements described has its own particular merits and limitations. The arrangement described in section 4.03.03 provides ready access to the plate holder or other detection equipment and allows observation of the central image for focusing. It suffers from the disadvantages of more hardware construction and light source inaccessibility. The section 4.03.04 arrangement may be obtained with a minimum of additional construction and has a much more accessible light source. On the other hand, access to the plate holder is restricted by the main vacuum chamber and observation of the central image for focusing would be difficult with the equipment installed in the vacuum chamber. However, the last problem can be overcome by performing initial alignment of the slits, grating and plate holder outside of the vacuum chamber. (This was the original intention of the author). Alignment could be made by removing the mounting platform from the chamber and clamping it in the correct location relative to the light source in a simple alignment jig. This jig would have the Rowland Circle center location marked by a hole so that the same measuring arm used for normal incidence alignment could be used in the same manner for grazing incidence. This scheme also allows observation of the central image during alignment. While the third arrangement requires only a small amount of hardware construction, the light source is inaccessible and the normal incidence equipment must be removed.

10.02.00: Grating Mount Conversion

The grating mount was constructed to allow rapid normal incidence to grazing incidence conversion. All that is required to make the change to the section 4.03.04 arrangement is to rotate the grating mount in the manner described in section 4.04.04. The section 4.03.03 conversion requires a similar rotation and the addition of a simple azimuth index and clamp. One particular precaution should be observed in such a conversion: The grazing incidence entrance slit and plate holder should be adjusted to the grating, and no attempt should be made to adjust the grating except in azimuth. Attempts to alter other adjustments will destroy the normal incidence adjustments and thus considerably increase the task of converting between normal and grazing incidence.

10.03.00: Grazing Incidence Plate Holder

Two acceptable grazing incidence plate holders are available. The normal incidence plate holder may be used at grazing incidence merely by moving it from the normal incidence position to the position prescribed in section 4.06.08 or to the location indicated in figure 4.03.03 if this arrangement is selected. The normal incidence film positioner mechanism could be used to support the plate holder at grazing incidence. However, this would require refocusing at each conversion. If such conversions are made often, it would be desirable to construct a second positioner mechanism. Because of the larger amount of astigmatism at grazing incidence, it would not be necessary to move the film holder vertically. It would be more desirable to use a moving mask for multiple exposures. Consequently, it would be possible and desirable to construct a less complex positioner mechanism having only focusing adjustments. It should be possible to design a mechanism that could remain in the instrument at all times.

As the normal incidence plate holder is considerably shorter than desired for the full grazing incidence range, use of the film holder from the old Chapin spectrograph would be desirable. This holder could be easily adapted to this instrument by shortening it and mounting it on a suitable mounting plate for mounting on the mounting platform.

Access to the grazing incidence plate holder for the section 4.03.04 configuration is through the six inch port on the side of the chamber at station line ≁16.625 and through the top port at station line ≁20.000.

10.04.00: Grazing Incidence Light Source Adapter

Conversion of the instrument for grazing incidence use would require the design and construction of a grazing incidence light source adapter. Construction of this adapter should not present any serious problems. Such an adapter for the figure 4.03.04 arrangement could be made by cutting a hole in the end plate and attaching a short line and supports for the slits and light source. In order to maintain vertical and lateral alignment between the light source slits and the grating and allow removal of the end plate, it would be necessary to add two dowel pins on each side of the large end flange and plate. Longitudinal alignment is no problem because the end plate is always drawn down to a metal to metal contact with the vacuum chamber end flange. An adapter for the figure 4.03.03 arrangement could be made by mounting the light source and slits in a tube mounted on a six inch flange of the type used to close the chamber access ports. Dowel pins would be required to insure repeatability of position.

11.00.00: PUMPING SYSTEM

11.01.01: Pumping Requirements

11.01.01: Ultimate Vacuum

An ultimate vacuum inside the main vacuum chamber on the order of 10^{-5} to 10^{-6} mmHg was desired. A total pump down time of no more than three or four hours was also desired.

11.01.02: Pumping Speed

The problem of pumping the system down and maintaining it at the desired pressure was complicated by the probable presence of two large operational leaks in addition to the usual problems of outgassing and leaks from the outside. A light source operating at a pressure on the order of 0.1 to 0.2 mmHg was anticipated. As the instrument was designed to be used for gaseous absorption work, etc., additional leaks inside the main chamber from detection apparatus were anticipated.

Calculations based upon the volume of the chamber and estimates of the various leaks expected indicated that a pumping speed on the order of five hundred liters per second would be necessary.

11.01.03: Pumping Speed Calculations

A brief examination of the pumping speed calculations is of interest. If line impedances are ignored, the rate of change of pressure inside the system is given by

$$\frac{dP}{dt} = -\frac{SP}{V} \qquad (11.01.02A)$$

where P = pressure, S = pumping speed, V = system volume and t = time in seconds. Solution of equation 11.01.02A for P gives:

$$P = P_o e^{-\left(\frac{St}{V}\right)} \qquad (11.01.02B)$$

The volume of the system is approximately 200 liters and the forepump pumping speed is approximately six liters per second. Solution of equation 11.01.02B for t for these conditions indicates that the time required to pump the system from atmospheric pressure to 100 microns (1.3×10^{-6} atmosphere), the diffusion pump turn on point, will require approximately 300 seconds if the pump is 100% efficient and if no outgassing occurs. Such calculations indicated that a 1/2 to 1 liter per second pump would be too slow and that a forepump faster than approximately 6 liters per second would be unnecessary.

The time required after diffusion pump turn on to reach lower pressures depends upon diffusion pump warm up time, outgassing and leaks. Attempts to compute times by merely inserting the diffusion pump speed and pressures into equation 11.01.02B and ignoring other factors give times on the order of a few seconds. Such values are ridiculous. Experience with the system indicates that times on the order of an hour or so are more realistic.

It can be shown that the throughput of a diffusion pump at 1,000 liters per second and one micron pressure is equal to that of a 6 liter per second forepump at 166 microns pressure. This indicates that the 6 liter per second forepump could handle the throughput of a 1,000 liter per second diffusion pump at all pressures at which it would pump with reasonable efficiency.

One of the principal factors in the determination of pumping speed for the diffusion pump was the leakage of gas into the system from the light source. A pump throughput of approximately 100 micron liters per second is required to handle the gas introduced from a light source slit 1 x 5 mm when the source pressure is 100 microns. This throughput can be realized at approximately 0.2 microns by a 500 liter per second pump. Differential pumping slits planned for the light source should reduce the calculated main chamber pressure by almost an order of magnitude.

11.02.00: Pumping System Description

11.02.01: Vacuum Pumps

The diffusion pump and fore pump are described in section 4.04.12. The diffusion pump has a rated pumping speed of 940 liters per second at 0.01 microns. The fore pump used is rated at 375 liters per minute. Provision was also made for attaching additional pumps in parallel with the large fore pump for increased roughing speed.

11.02.02: Pump Location and Connections

The HV-6F oil diffusion pump (11.01.01) is suspended directly below the main chamber from the six inch bottom port. An "O" ring seal supplied with the pump provides a vacuum seal between the pump and the main chamber.

A fore pump header assembly (11.02.01) is attached to the diffusion pump exhaust. This assembly has provisions for mounting vacuum gauges. Vacuum valves 11.02.04 and 11.02.05S2 attached to the header exhausts make it possible to isolate the pumps from the diffusion pump. The fore pumps are connected to the valves by rubber tubing.

11.03.00: Pumping System Controls

11.03.01: Fore Pump Controls

The large fore pump (11.03.00S1) is controlled and fused from control panel 11.05.00 located on one of the two six foot instrumentation racks with the remainder of the instrument controls. A similar control panel (11.04.00) provides control and fusing for up to three smaller pumps operating from 115V, 60 cps lines.

11.03.02: Diffusion Pump Controls

The diffusion pump is controlled and fused from diffusion pump control panel 11.06.00 mounted on the instrumentation racks. This panel provides connections for water and fore pressure switches used to cut off the diffusion pump heater if either the water pressure or the fore pump fail. An outlet for the control of a solenoid water valve to turn on and shut off the cooling water with the pump heater power is available.

11.04.00: Pumping System Installation

11.04.01: Diffusion Pump Installation

After filling the diffusion pump with HV-40 oil, it is bolted to the bottom flange of the main chamber with 8.02.11 bolts and 8.03.12 nuts. An "O" ring gasket is used between the pump and the flange. The pump is oriented so that the exhaust flange will be on the front side of the spectrograph and slightly toward the detector end.

11.04.02: Fore Pump Header Installation

The fore pump header (11.02.00) is bolted to the diffusion pump exhaust flange so that it will run parallel to the spectrograph center line and toward the grating end. An "O" ring supplied with the pump is used between the pump and the header. The header is bolted in place with 11.02.06 bolts and 11.02.07 nuts. Valves 11.02.04 and 11.02.05 are screwed into place with the handles to the front of the spectrograph. Threads are coated with black glyptal. Reducers 11.02.02 and 11.02.03 are used as required to connect to the fore pump hoses.

11.04.03: Main Fore Pump Installation

The large Welch Pump (11.03.00) is placed directly under the vacuum chamber and connected to the 1-1/2" header valve by a short length of rubber hose connected to pipe nipple 11.03.08S1, screwed into valve 11.02.05S1.

11.04.04: Control Box Installation

The control boxes are all mounted on the instrumentation racks. Electrical connections to the main pump and diffusion pump are made with No. 12 double wire cable. No. 18 rubber extension cord is used elsewhere.

11.05.00: Equipment Purchase and Construction

All necessary part purchase and construction information is given by the 11.00.00 series drawings at the end of this chapter. See drawing 11.00.00-A.

Drawing 11.00.00-A
Pumping System
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y No.	Dwg. No:	Note:	Description:
11.00.00	11.00.00-A		Pumping System
11.01.00	None		Diffusion Pump, High Vacuum Corp. HV-6F six inch oil diffusion pump with HV-40 oil and gaskets.
11.02.00	11.02.00-A		Fore Pump Header Ass'y.
11.03.00	None		Fore Pump, Welch 1397B.
11.04.00	11.04.00-A		Fore Pump Control Panel
11.05.00S1	None		Fore Pump Control Box, 220V, 2 wire, 220V, 15A breaker box
11.06.00	11.06.00-A		Diffusion Pump Control Panel

Drawing 11.02.00-A

Fore Pump Header Ass'y.
Vacuum Spectrograph
M.S.M. Physics Department

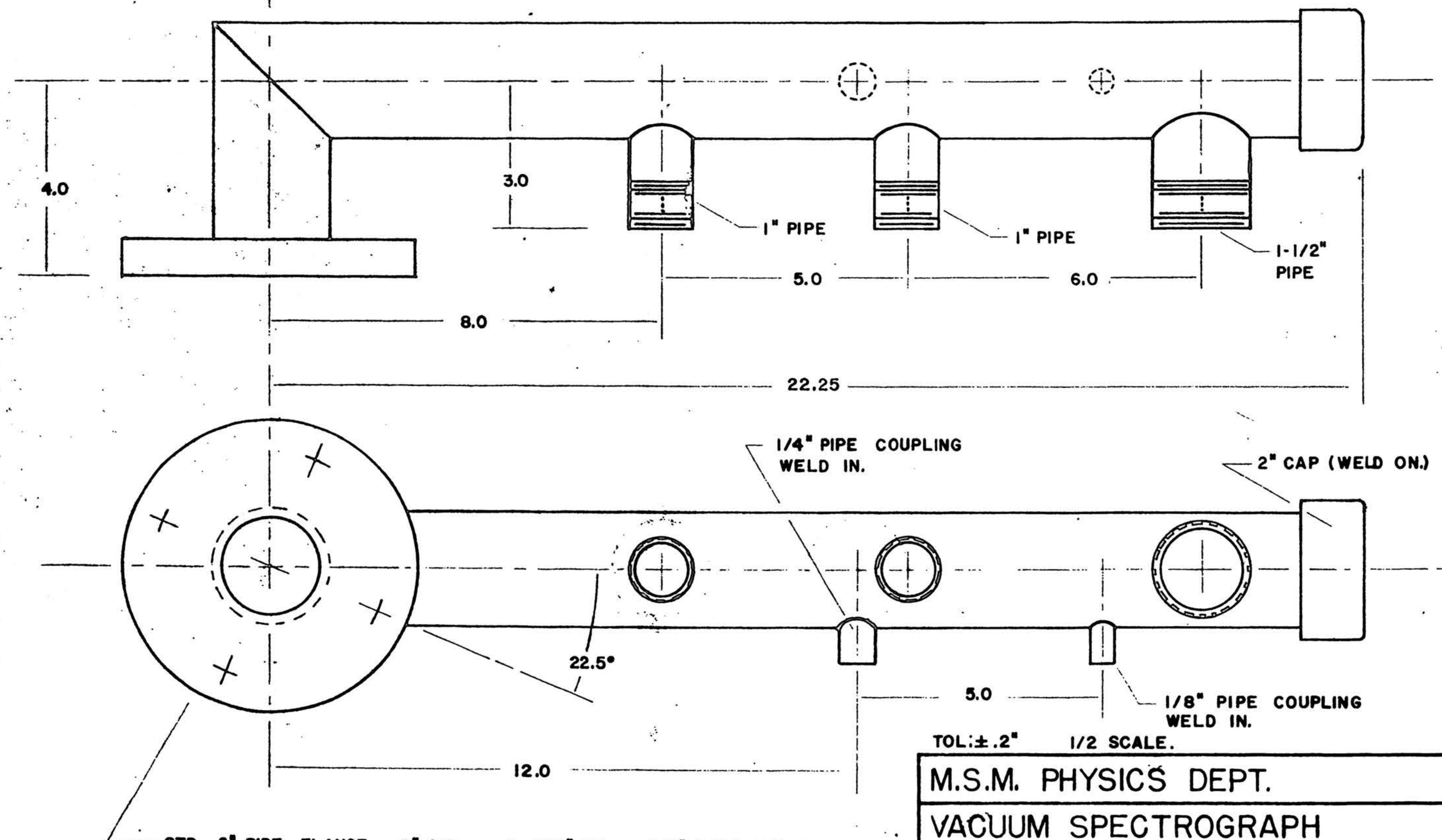
PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
11.02.00	11.02.00-A		Fore Pump Header Ass'y.
11.02.01	11.02.01	A	Fore Pump Header
11.02.02-2	11.02.02		1" to 1/2" Reducer
11.02.03	11.02.03		1-1/2" to 1/2" Reducer
11.02.04S2	None		Valve, high vacuum, 1"
11.02.05S1	None		Valve, high vacuum, 1-1/2"
11.02.06S4	None		Bolt, hex, 2-1/2", 5/8" N.C., steel
11.02.07S4	None		Nut, hex, 5/8" N.C., steel
11.02.08S1	None		Pipe Nipple, 4", 1-1/2" dia., iron

ASSEMBLY NOTES:

(A)

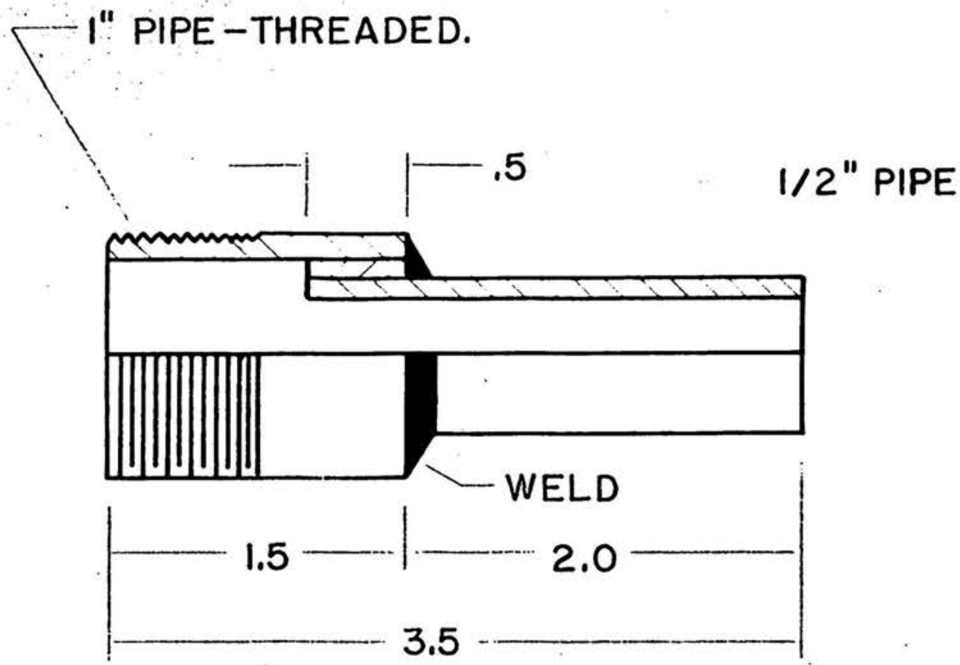
Assemble header as indicated in dwg. 11.02.01.



STD. 2" PIPE FLANGE— 6" O.D.— 4-3/4" B.C.— 5/8" BOLT HOLES.
FLANGE FACE MUST BE SMOOTH.
NOTE: MAIN PIPE IS 2".

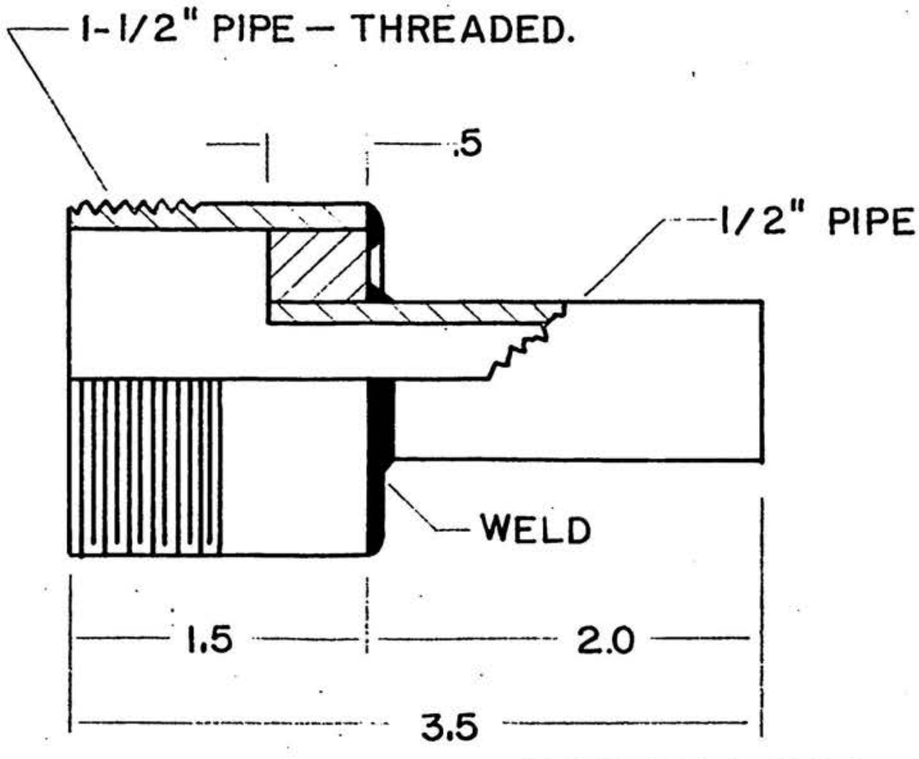
TOL.:± .2" 1/2 SCALE.

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
5/6/56	FORE PUMP HEADER
J.K.H.	11.02.01



MATERIAL: IRON

REDUCER: 1"– 1/2"	11.02.02



MATERIAL: IRON

REDUCER: 1-1/2"— 1/2"	11.02.03

M.S.M. PHYSICS DEPT.

VACUUM SPECTROGRAPH

Drawing 11.04.00-A
Fore Pump Control Panel
Vacuum Spectrograph
M.S.M. Physics Department

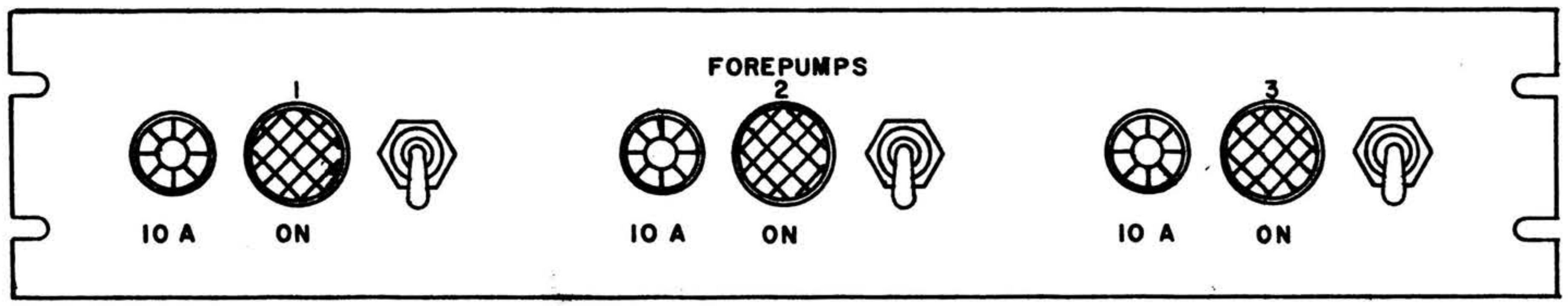
PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
11.04.00	11.04.00-A	A	Fore Pump Control Panel
	11.04.00-B		Panel & Rear View
	11.04.00-C		Elect. Schematic
11.04.01S1	None		3-1/2" x 19" x 1/8" Al. Rack Panel, grey finish
11.04.02S1	None		7" x 17" x 3" Chassis Base, steel I.C.A. 1528
11.04.03S3	None		Pilot Lamp, red, Dialco C431
11.04.04S3	None		Pilot Lamp Bulb, 115V
11.04.05S3	None		Fuse Mount, Littelfuse 342001
11.04.06S3	None		Fuse, 10 Amp., Littelfuse 314010
11.04.07S3	None		Jack, chassis mtg., female, 2 prong, Amphenol 61F
11.04.08S1	None		Plug, chassis mtg., male, 2 prong, Amphenol 61M
11.04.09S3	None		Switch, toggle, SPST, 15 amp., C-H 7501-K13

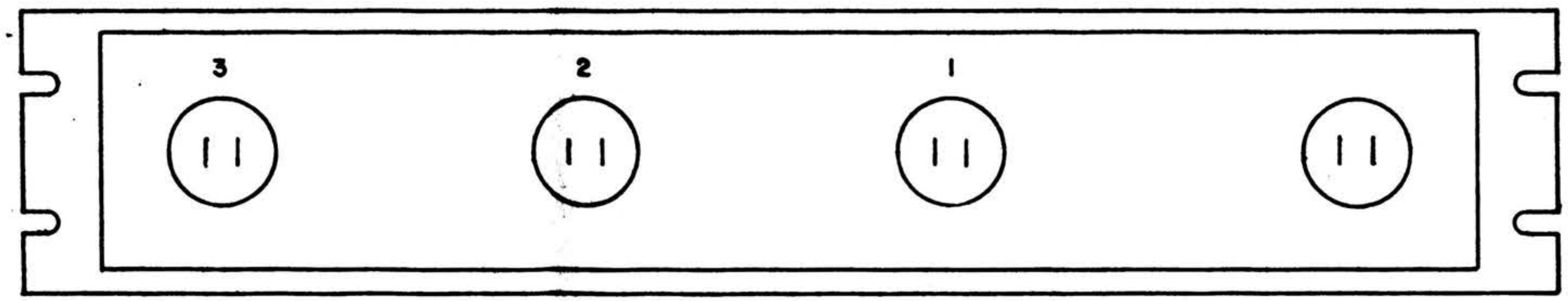
ASSEMBLY NOTES:

(A)

Assemble as per dwg. 11.04.00-B and wire as per dwg. 11.04.00-C.



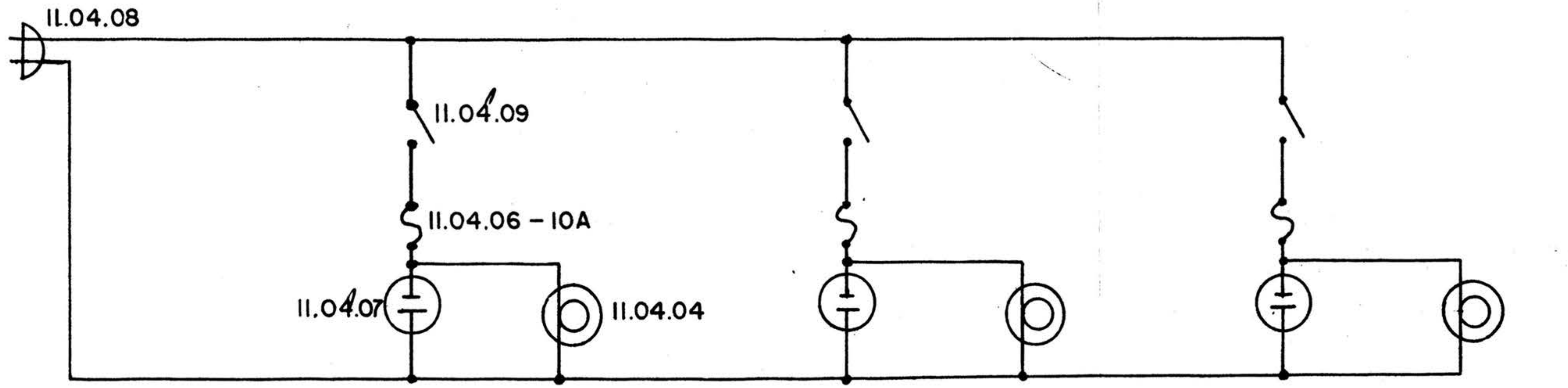
FRONT VIEW



REAR VIEW

HALF SCALE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/26/56	FOREPUMP SWITCH PANEL
DRAWN BY: D.D.H.	11.04.00-B



ELECTRICAL SCHEMATIC

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	FOREPUMP CONTROL PANEL
JKH	DWG. 11.04.00-C

Drawing 11.06.00-A
Diffusion Pump Control Panel
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

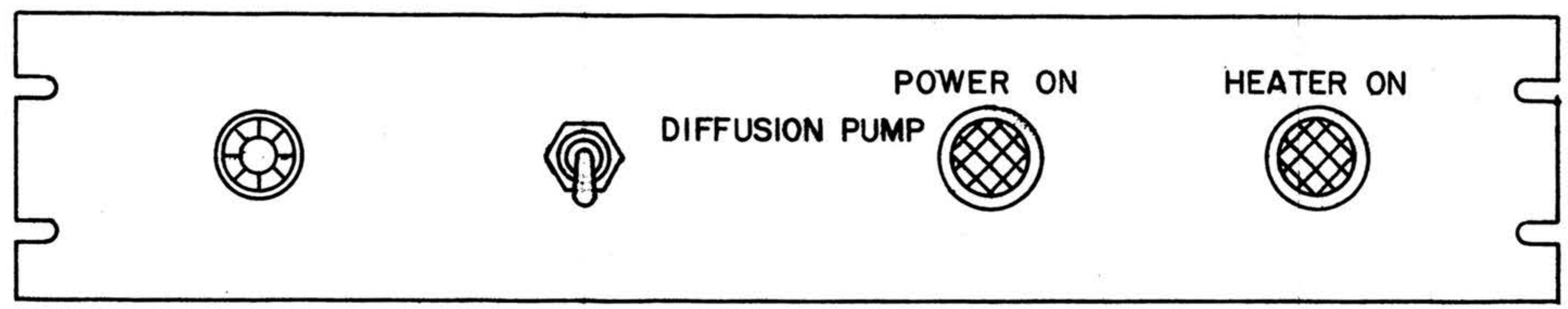
Part No:	Dwg. No:	Note:	Description:
11.06.00	11.06.00-A	A	Diffusion Pump Control Panel
	11.06.00-B		Panel & Rear View
	11.06.00-C		Elect. Schematic
11.06.01S1	None		Plug, chassis mtg., male, 2 prong, Amphenol 61-M
11.06.02S2	None		Jack, chassis mtg., female, 2 prong, Amphenol 61-F
11.06.03S1	None		Switch, SPST, toggle, C-H 8280-K16
11.06.04S1	None		Relay, SPST, N.O., 115V coil, 15 amp.
11.06.05S2	None		Pilot Lamp, red, 115V, Dialco C431
11.06.06S2	None		Pilot Lamp Bulb, 115V, GE S6
11.06.07S1	None		Panel, 3-1/2" x 19" x 1/8", aluminum, grey finish
11.06.08S1	None		Chassis Base, 8" x 17" x 3", steel. I.C.A. 1575
11.06.09S2	None		Terminal Strip, Allied 40H995
11.06.10S2	None		Jack, chassis mtg., 4 pin, female, Amphenol 78S4

Part No:	Dwg. No:	Note:	Description:
11.06.11S2	None		Plug, line, 4 pin, male, Amphenol 86PM4
11.06.12S1	None		Fuse Mount, Littelfuse 342001
11.06.13S1	None		Fuse, 15A, Littelfuse 314015

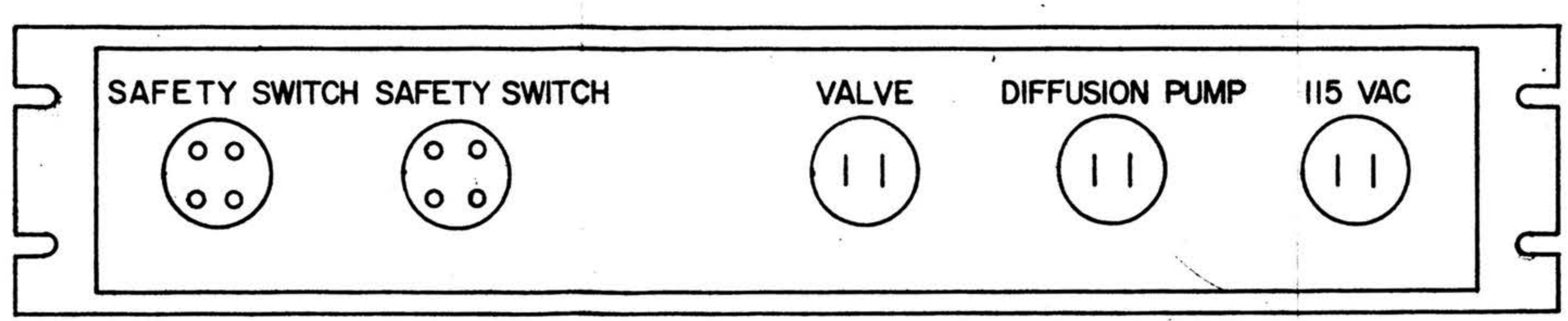
ASSEMBLY NOTES:

(A)

Assemble panel as per dwgs. 11.06.00-B and wire as per dwg. 11.06.00-C.



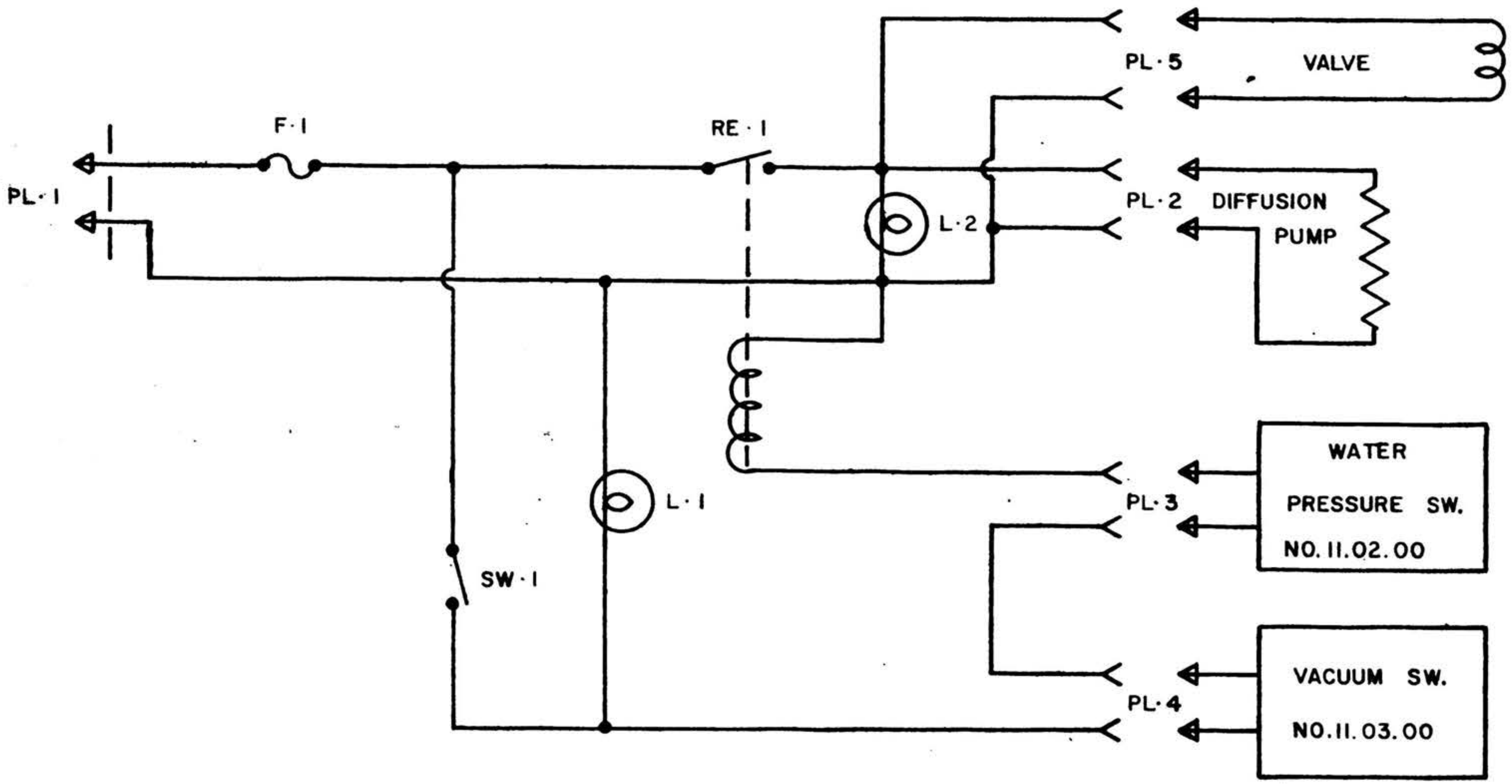
FRONT VIEW



REAR VIEW

HALF SCALE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/26/56	PUMP CONTROL
DRAWN BY: D.D.H.	11.0600-B



SCHEMATIC DIAGRAM

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/28/56	DIFFUSION PUMP CONTROL
DRAWN BY: D.D.H	DWG. NO. 11.06.00-C

12.00.00: PRESSURE MEASUREMENT

12.01.00: Gauge Types

Two types of gauges are used for pressure measurements in this instrument in order to cover the required range of pressures. Pressures in the 1 to 1,000 micron range are measured by National Research type 501 thermocouple gauges. Lower pressures are measured by Phillips cold cathode ionization gauges (PIG). A control unit for use of hot cathode ionization gauges is available for measurement of pressures beyond the range of the PIG, however, this unit has not been used.

12.02.00: Phillips Ionization Gauge (PIG)

A Phillips ionization gauge (12.02.00) is mounted in the six inch flange on the top of the main chamber at station line ≠20.000.

12.03.00: Thermocouple Gauges

Thermocouple gauges 12.01.01 are used on the fore pump line, at the top six inch port at S.L. ≠20.000 and on the light source. The thermocouple gauge control panel (12.01.00) is capable of handling five such gauges. The gauge to be read is selected by a selector switch on the control panel. The filaments for the gauges in use are turned on by toggle switches one through five on the panel.

As the calibration for thermocouple gauges depends upon the filament temperature, consequently, a potentiometer and meter for regulating the filament current are available on the control panel. The recommended heater current for the N.R. 501 gauges is 0.65 Ampere. (A matched set of five with this current was purchased.)

The calibration of one of these gauges was checked against a McLeod gauge. (The manufacturer's calibration curve was used.) The readings compared exactly at 17 microns and were within two microns at other points up to 68 microns. The accuracy of this comparison was $\pm$2.5 microns.

In order to utilize the gauge at higher pressures, it was calibrated at a filament current of 0.80 Amperes against a McLeod gauge. The resulting calibration curve (good to 3 microns) is plotted in figure 12.03.00-A.

12.04.00: Hot Cathode Ionization Gauge

A control unit for hot cathode ionization gauges that was on hand in the department was mounted in the instrumentation rack. However, the shortage of time did not permit installation or calibration of the gauges.

12.05.00: Equipment Purchase and Construction

All necessary purchase and construction information is given by the 12.00.00 series drawings. See drawing 12.00.00-A.

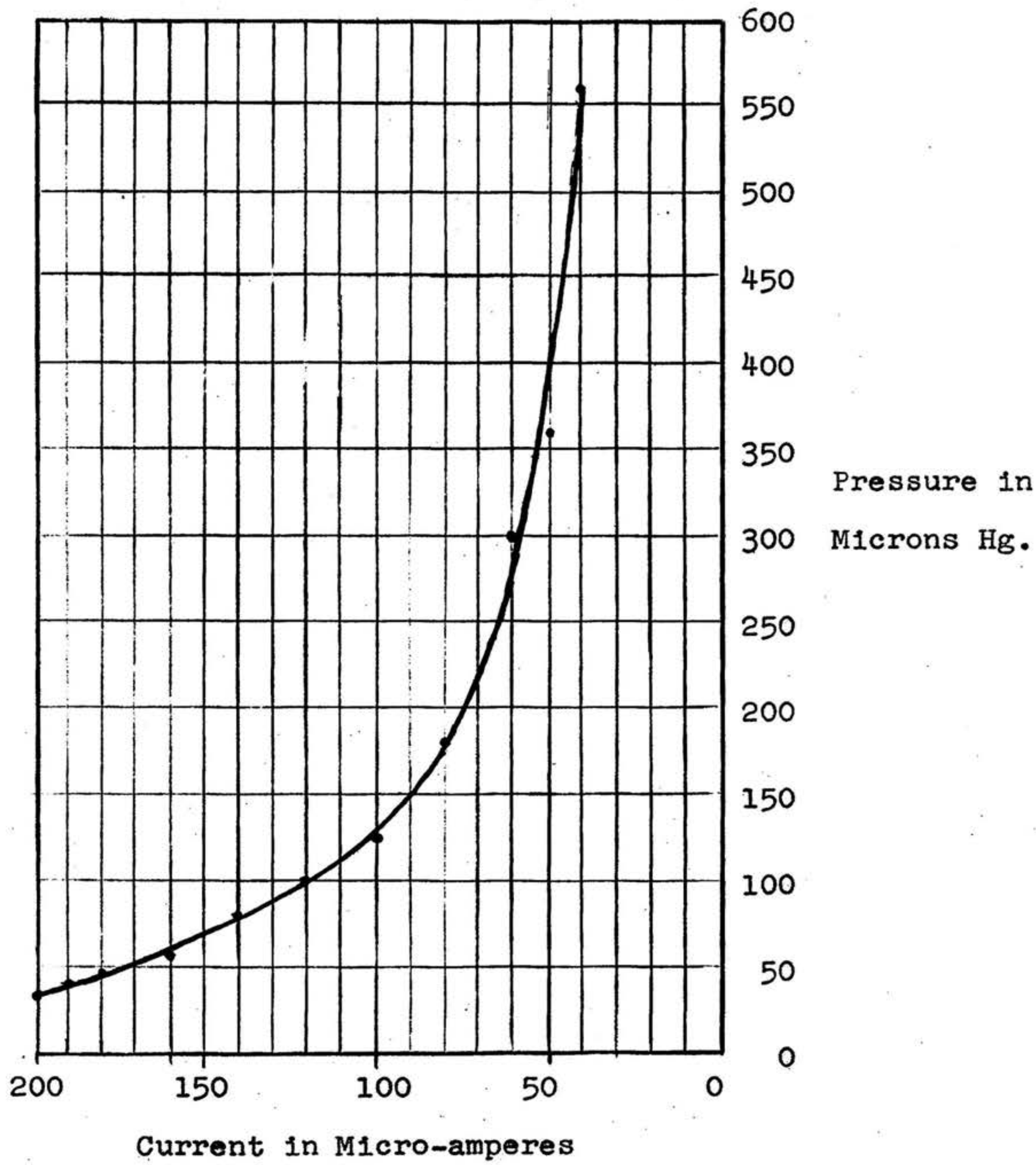


Figure 12.03.00A: Thermocouple Gauge Calibration Curve for 0.80 Ampere Heater Current

Drawing 12.00.00-A | Sheet 1 of 1

Pressure Measuring Equipment
Vacuum Spectrograph
M.S.M. Physics Department

ASSEMBLY AND DRAWING LIST:

Ass'y. No:	Dwg. No:	Note:	Description:
12.00.00	12.00.00-A		Pressure Measuring Equipment
12.01.00	12.01.00-A		Thermocouple Gauge
12.02.00	None		Phillips Ionization Gauge
12.03.00	None		Ionization Gauge Control Unit (Available in Department)

Drawing 12.01.00-A
Thermocouple Gauge
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

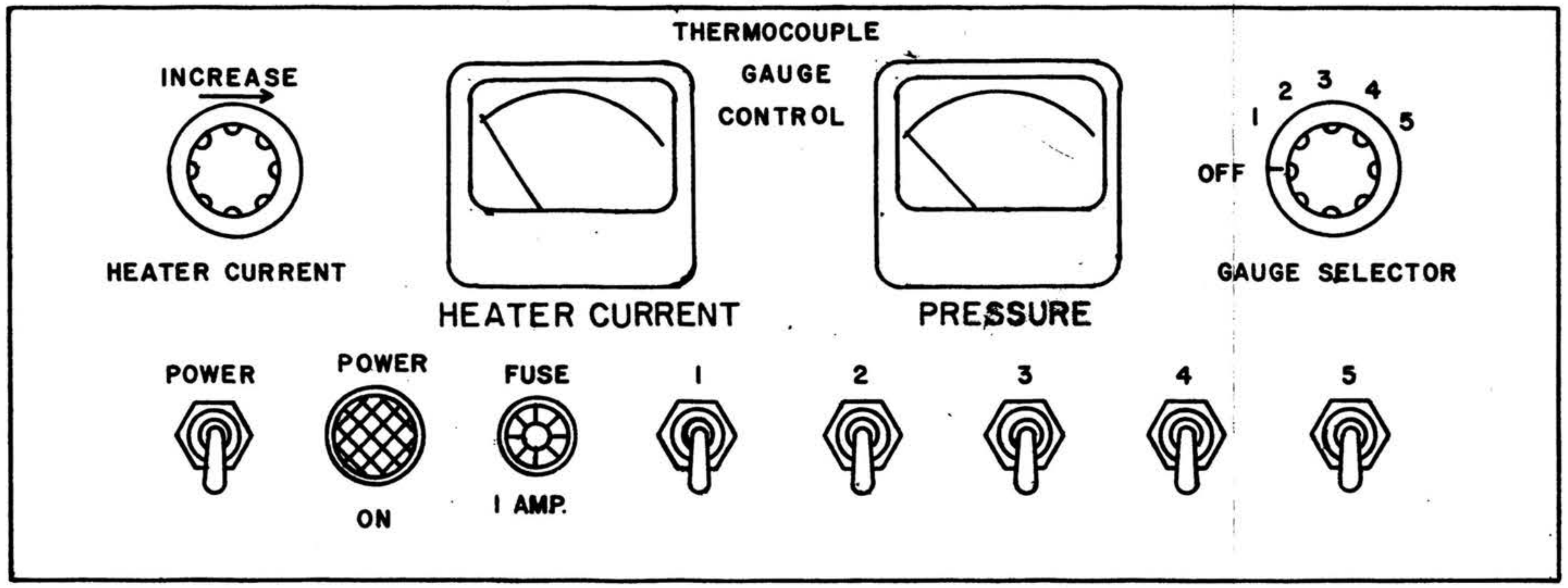
Part No:	Dwg. No:	Note:	Description:
12.01.00	12.01.00-A	A	Thermocouple Gauge Control Panel
	12.01.00-B		Panel View
	12.01.00-C		Elect. Schematic
	12.01.00-F		Rear View
12.01.01S5	None		Thermocouple Gauge, National Research Co., Type 501, (matched set of five)
12.01.02S1	None		Meter, 0 to 1 Amp., A.C., Triplett 337S
12.01.03S1	None		Meter, 0 to 200 UA, D.C., 55 ohm internal resistance, Weston type 301
12.01.04S1	None		Switch, rotary, 6 pos., 2 pole, Mallory type 1315L
12.01.05S1	None		Switch, toggle, SPST, C-H 8280-K16
12.01.06S6	None		Switch Plate, ON-OFF, C-H 20590-1
12.01.07S5	None		Resistor, wirewound, 0.24 ohm, 1/2 W.
12.01.08S2	None		Resistor, 3.9 ohm, wirewound, 2 W.
12.01.09S1	None		Resistor, 29 ohm, wirewound, 1/4 W.
12.01.01S1	None		Resistor, variable, 3 ohm, 3 W. I.R.C. W3

Part No:	Dwg. No:	Note:	Description:
12.01.11S1	None		Pilot Light Ass'y. 6.3 V, Allied No. 52E545
12.01.12S1	None		Pilot Light, No. 47
12.01.13S1	None		Fuse Mount, Littel-fuse 372001
12.01.14S1	None		Fuse, instrument, 1A, type 8AG
12.01.15S1	None		Transformer, 115V prim., 6.3 V C.T. secondary, 1A, Thordarson 21F08
12.01.16S5	None		Socket, octal, Amphenol 78S8
12.01.17S1	None		Plug, chassis mtg., 2 prong, Amphenol 61-M
12.01.18S5	None		Switch, toggle, SPDT, C-H 8282-K14
12.01.19S2	None		Terminal Strip, Cinch-Jones 10-170
12.01.20S1	None		Chassis, 2" x 17" x 8", steel, Bud CB-1764
12.01.21S1	None		Panel, 7" x 19" x 1/8" rack, grey
12.01.22S2	None		Bracket, Bud M.B. 458
12.01.23S2	None		Knob, fluted, 1-5/8" Allied 55H095

ASSEMBLY NOTES:

(A)

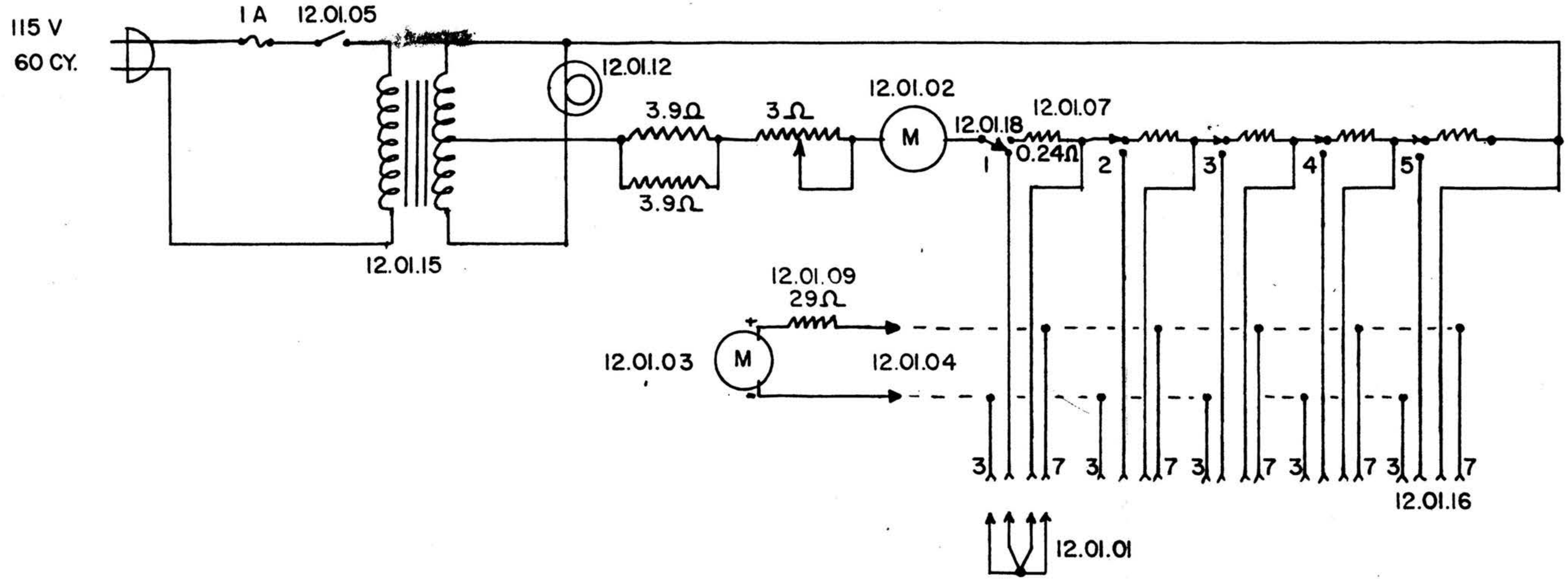
Assemble as shown in dwgs. 12.01.00-B & F. Transformer 12.01.15S1 is mounted at back edge of chassis. Wire as indicated by dwg. 12.01.00-C.



FRONT VIEW

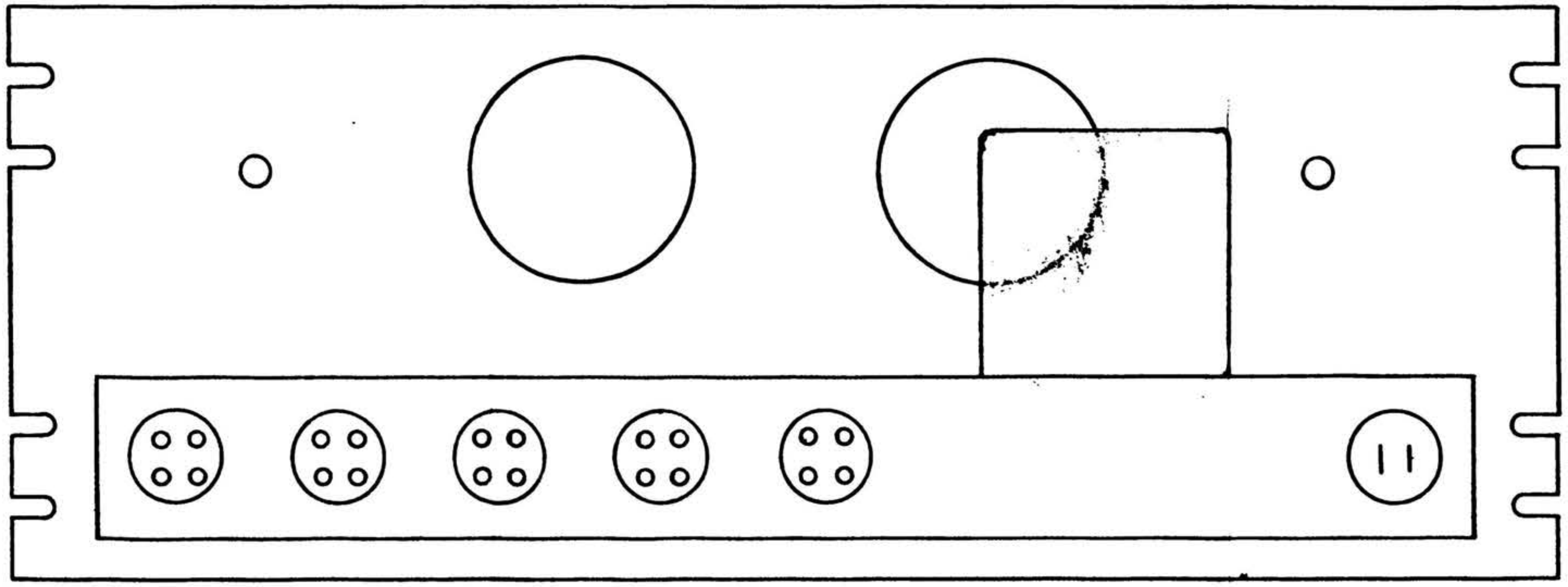
HALF SCALE

M.S.M PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/27/56	THERMOCOUPLE GAUGE CONTROL
DRAWN BY: D.D.H.	DWG. NO. 12.01.00.B



ELECTICAL SCHEMATIC

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
	THERMOCOUPLE GAUGE
JKH	DWG. 12.01.00-C



REAR VIEW

HALF SCALE

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/28/56	THERMOCOUPLE GAUGE CONTROL
DRAWN BY: D.D.H.	DWG. 12.01.00.F

13.00.00: POWER DISTRIBUTION

13.01.00: Main Power Panel

All a.c. power for the entire spectrograph is distributed through the Main Power Panel (13.01.00) located at the bottom of one of the equipment racks. Three wire, sixty Ampere, 220 volt power is brought into this panel directly from the building power panel. Two pilot lights on the front of this panel indicate power on each main buss.

Power for the light source high voltage power supply is not fused on this panel. This circuit is capable of a fifty Ampere load. One ten Ampere fused line is also provided for the light source.

Two twenty-five Ampere circuits for the two Rack Power Panels (13.02.00) and three five Ampere circuits are provided at jacks at the rear of the panel.

13.02.00: Rack Power Panels

All 115 volt a.c. power used on the two equipment racks is distributed by a Rack Power Panel (13.02.00) at the bottom of each rack. An indicator light indicates that power is on the rack. Eight standard two prong electrical outlets are provided at the rear of these panels.

13.03.00: Power Panel Construction

All construction information for the power panels is given by the series 13.00.00 drawings. See drawing 13.00.00-A.

Drawing 13.00.00-A
Power Distribution System
Vacuum Spectrograph
M.S.M. Physics Department

Sheet 1 of 1

ASSEMBLY AND DRAWING LIST:

Ass'y. No:	Dwg. No:	Note:	Description:
13.00.00	13.00.00-A		Power Distribution System
13.01.00	13.01.00-A		Main Power Panel
13.02.00-2	13.02.00-A		Rack Power Panel

Drawing 13.01.00-A
Main Power Panel
Vacuum Spectrograph
M.S.M. Physics Department

PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
13.01.00	13.01.00-A 13.01.00-B 13.01.00-C 13.01.00-F	A	Main Power Panel Front Panel Electrical Schematic Rear View
13.01.01S1	None		Panel, 8-3/4" x 19" x 1/8" Al. rack, grey finish
13.01.02S1	None		Chassis, 8" x 17" x 3", 1/16" steel, ICA 1575
13.01.03	13.01.00-F	1	Cover Plate
13.01.04	13.01.00-F	1	Cover Plate
13.01.05	13.01.00-F	1	Cover Plate
13.01.06S3	None		Jack, chassis mtg., 2 prong, female, Amphenol 61-F
13.01.07S2	None		Pilot Light Ass'y., red, 115V, Dialco series 75, C-431
13.01.08S2	None		Pilot Light Bulb, 115V, GE-S6
13.01.09S2	None		Cable Clamp for 2-12, non-metallic sheathed cable
13.01.10S2	None		Cable Clamp for 3-6, non-metallic sheathed cable
13.01.12S2	None	B	Standoff, 3", steel

PART AND DRAWING LIST (Cont'd):

Part No:	Dwg. No:	Note:	Description:
13.01.13S6	None		Fuse Mount, Littelfuse 342001
13.01.14S2	None		Fuse, 30 Amp., Littelfuse 314030
13.01.15S1	None		Fuse, 10 Amp., Littlelfuse 314010
13.01.16S3	None		Fuse, 5 Amp., Littlelfuse 314005
13.01.17S1	None	C	Cable, 15', 6.3 sheathed cable
13.01.18S1	None		Plug, 3 wire 60 Amp. range plug
13.01.19S1	None		Cable Clamp for 6.3 sheathed cable
13.01.20S1	13.01.00-B		4" x 4" card holder ass'y.
13.01.21S3	None	D	Terminal Strip, insulated, 5 terminal buss, terminals for #6 wire

FABRICATION NOTES:

(1)

Cut plates as indicated in dwg. 13.01.00-F from 1/16" steel chassis cover plate.

ASSEMBLY NOTES:

(A)

Assemble as indicated by drawings 13.01.00-B & F. Wire in accordance with dwg. 13.01.00-C. Heavy line indicates #6 or larger buss (terminal strips (13.01.21S3).

ASSEMBLY NOTES (Cont'd):

(B)

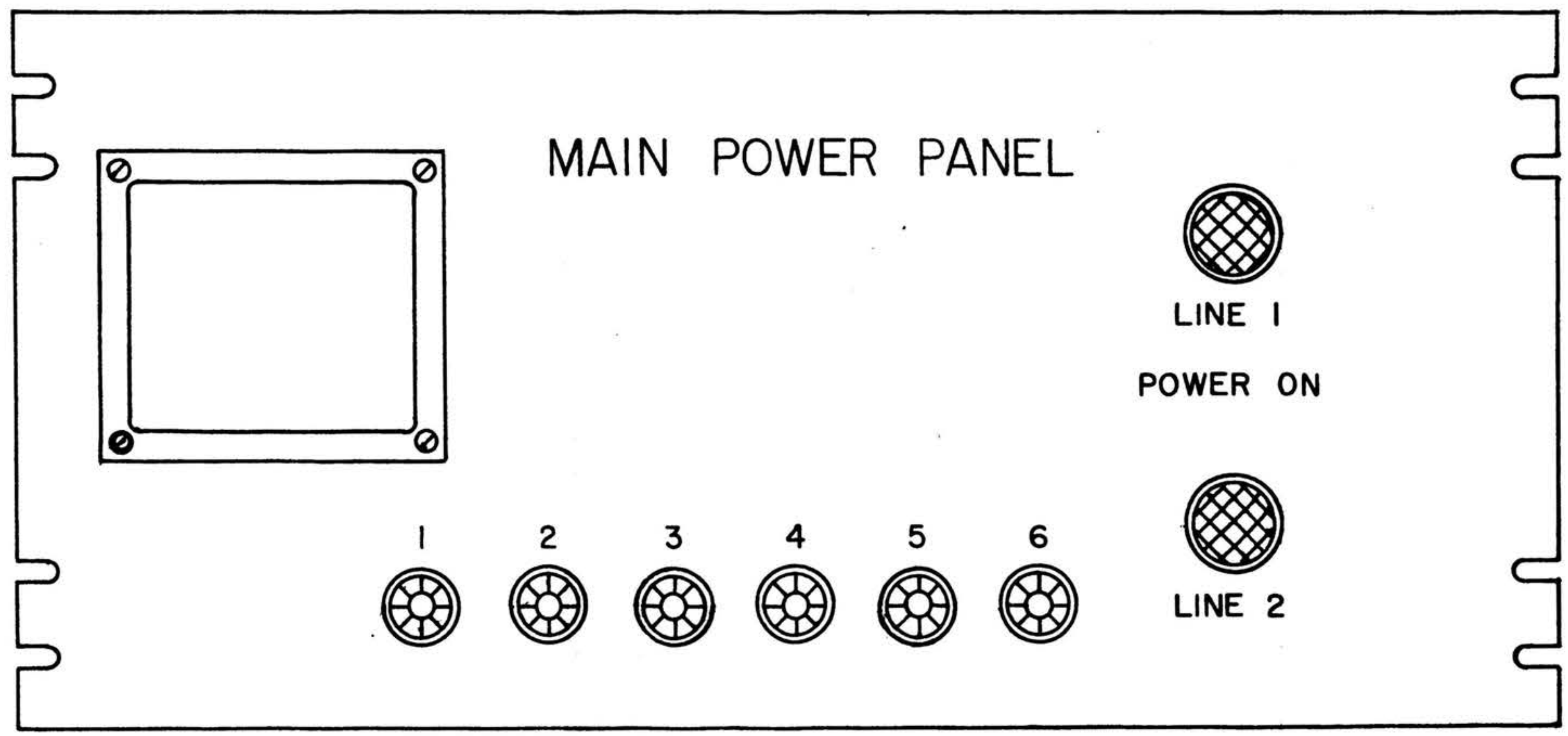
Standoffs are used to support inside centers of cover plates 13.01.03 & 13.01.05.

(C)

Cable is used to run from building power panel receptacle to power panel. Cable is clamped with clamp 13.01.19S1 at hole in cover plate 13.01.05.

(D)

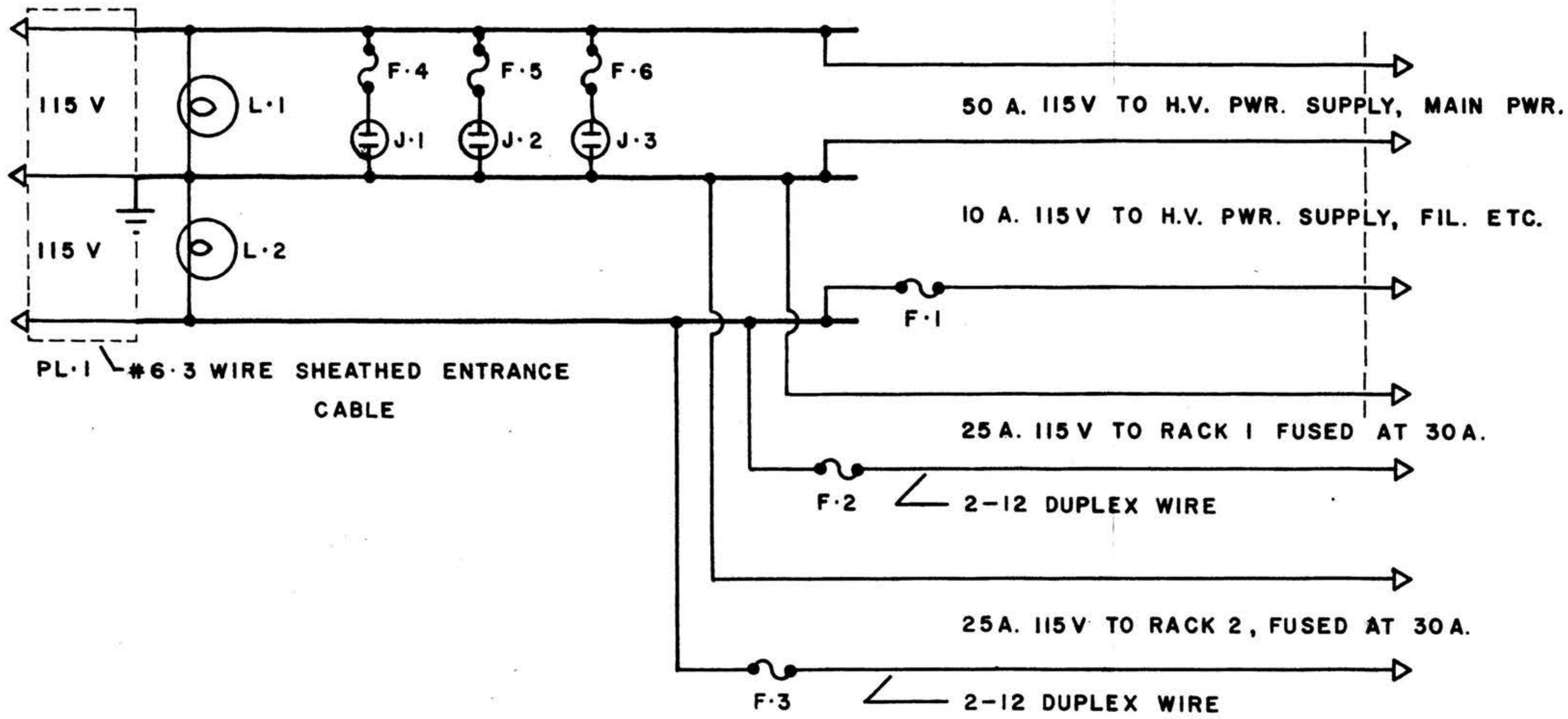
Terminal strips are used as #6 buss for power cable termination.



FRONT VIEW

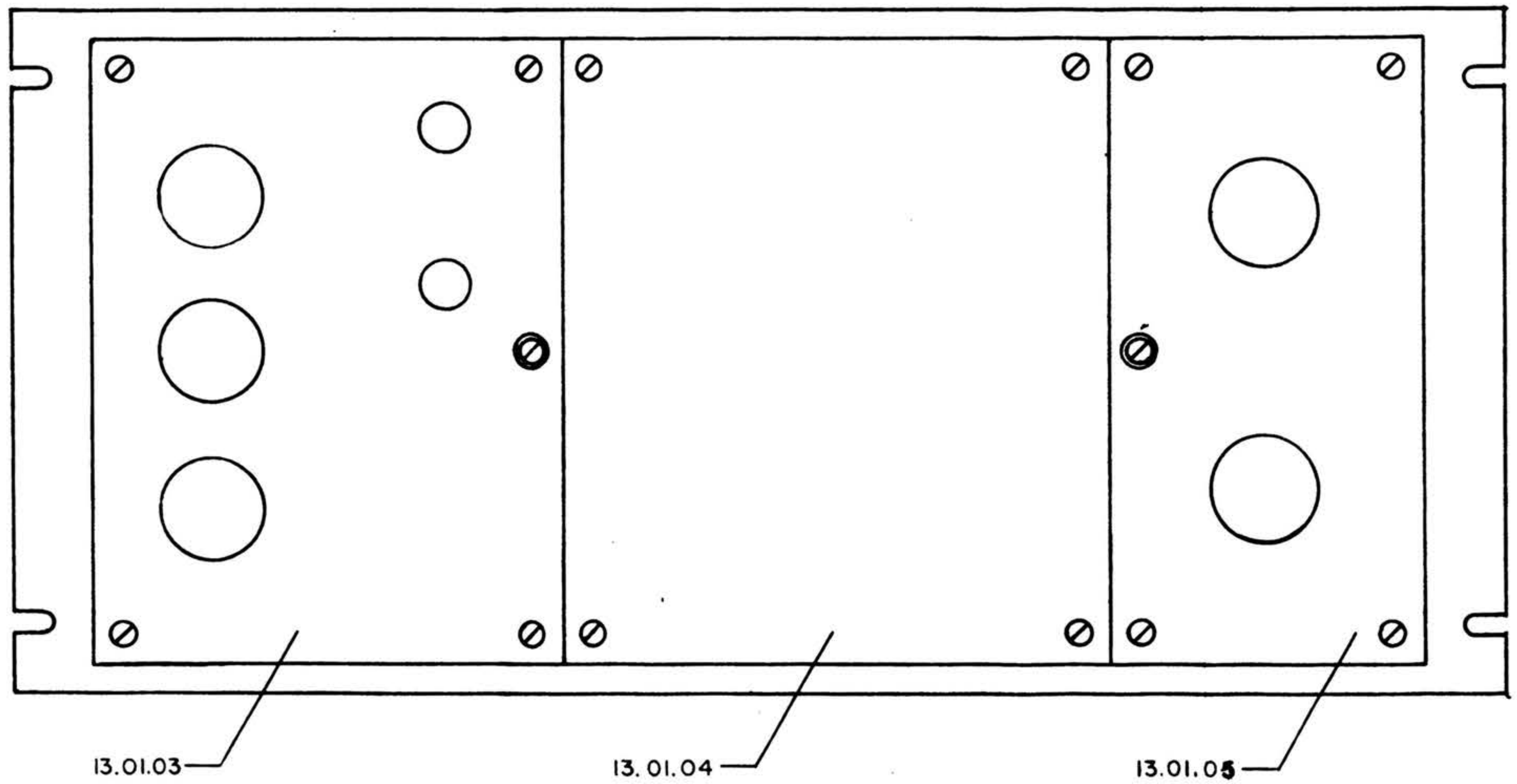
HALF SCALE

M.S.M. PHYSICS DEPT.	
VACUUM SPETROGRAPH	
12/27/56	MAIN POWER PANEL
DRAWN BY: D.D.H.	DWG. NO. 13.01.00.B



SCHEMATIC DIAGRAM

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
1/2/57	
DRAWN BY: D.D.H.	DWG. NO. 13.01.00.C



REAR VIEW

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/26/56	MAIN POWER PANEL
DRAWN BY: D.D.H.	13.01.00-F

Drawing 13.02.00-A
Rack Power Panel
Vacuum Spectrograph
M.S.M. Physics Department

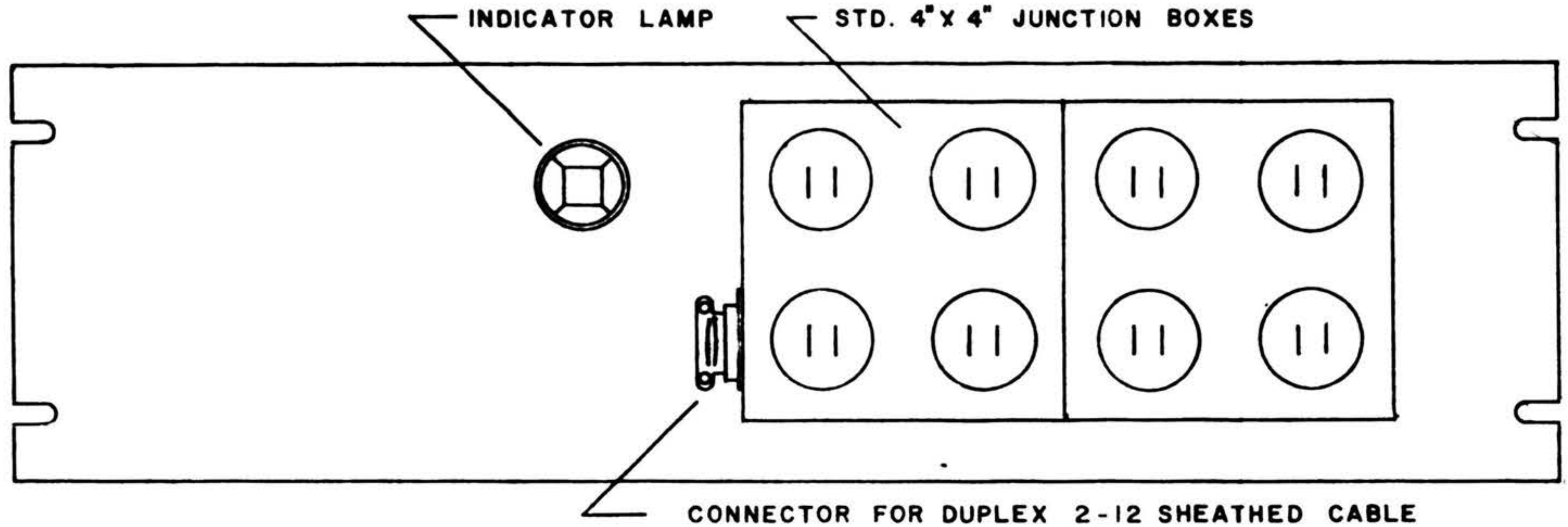
PART AND DRAWING LIST:

Part No:	Dwg. No:	Note:	Description:
13.02.00-2	13.02.00-A 13.02.00-B	A	Rack Power Panel Panel & Rear View
13.02.01S1	None		5-1/4" x 19" x 1/8" Al. rack panel, grey finish
13.02.02S1	None		Pilot Lamp Ass'y. 115V, red, Dialco C-431
13.02.03S1	None		Pilot Lamp Bulb, 115V, GE-S6
13.02.04S2	None		Box, 4" x 4" elect. junction, surface mtg.
13.02.05S2	None		Double outlet adapters for 4" x 4" elect. box
13.02.06S4	None		Double electrical outlet, heavy duty
13.02.07S1	None		Cable Clamp for 2-12 non-metallic sheathed cable
13.02.08S1	None		6' length of 2-12 non-metallic sheathed cable

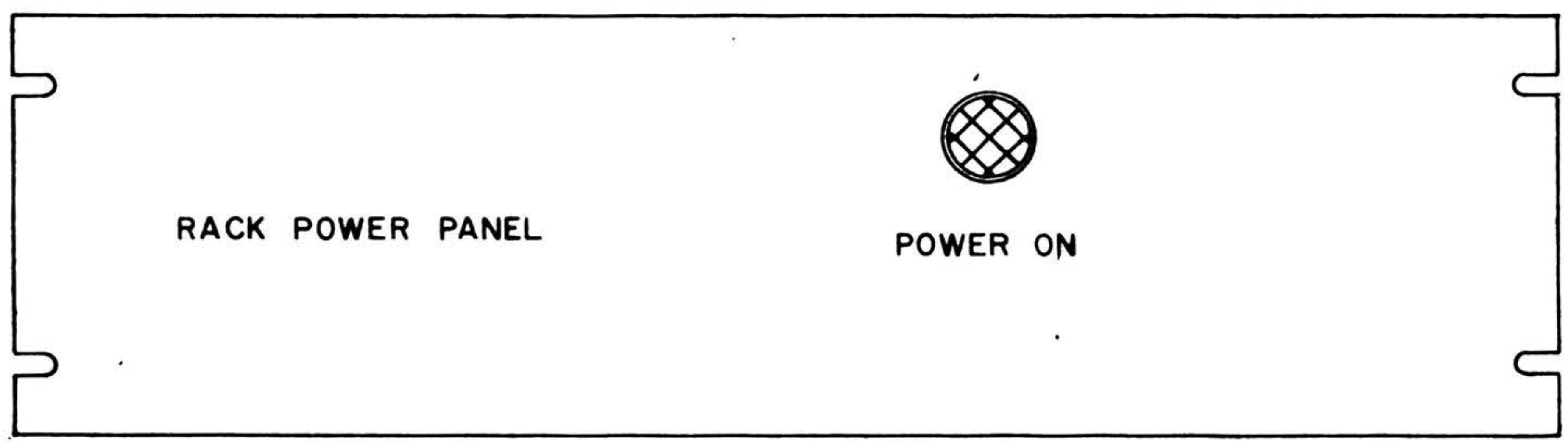
ASSEMBLY NOTES:

(A)

Assembly as per dwg. 13.02.00-B. Wire all outlets in parallel. Connect to Main Power Panel (13.01.00) buss by cable 13.02.07S1.



REAR VIEW



FRONT VIEW

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
12/27/56	RACK POWER PANEL
DRAWN BY: D.D.H.	DWG. 13.02.00.B

14.00.00: PROJECT STATUS AND RECOMMENDATIONS

14.01.00: Degree of Completion

The shortage of time and the lack of the services of a machinist prevented completion of the spectrograph. However, the major portion of the instrument was completed to the extent that the normal incidence capability could be, and was, put into operation with only the addition of a suitable light source and entrance slit.[1] (The design and construction of the light sources were not a part of the author's task. The normal incidence light source was constructed by Mr. Robert Peercy.)

The only major tasks remaining incomplete are the actual construction of the normal incidence mask assembly, the film drive linkage, some necessary rework of the grating mount drive mechanism and construction of the grating drive control panel. All of the design work in these areas has been completed. As pointed out in section 10, the grazing incidence entrance line was neither designed nor built.

The exact status of each portion of the project is summarized below.

5.00.00: Grating Mount and Drive Mechanism

The Grating Mount was completed in the form shown in figures 14.01.00-A, B & C. However, the drive mechanism proved unsatisfactory and had to be redesigned. The redesigned unit is described in section 5.00.00. The drive

(1) Peercy, Robert L., Jr., Design and Construction of a Light Source and Detection System for a Vacuum Spectrograph, Unpublished M.S.M. Masters Thesis, 1961.

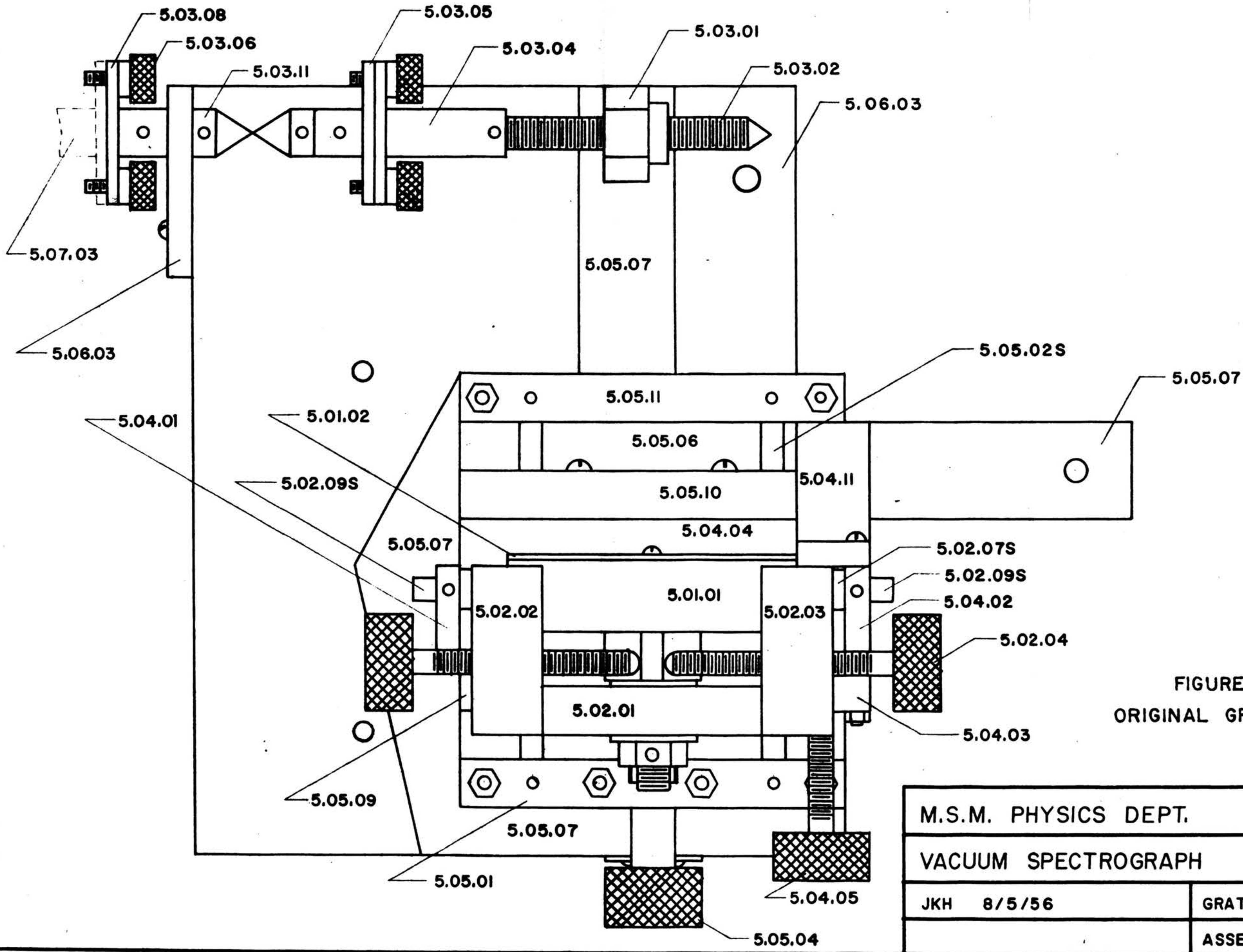


FIGURE 14.01.00A
ORIGINAL GRATING MOUNT

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 8/5/56	GRATING MOUNT — TOP VIEW
	ASSEMBLY No. 5.00.00

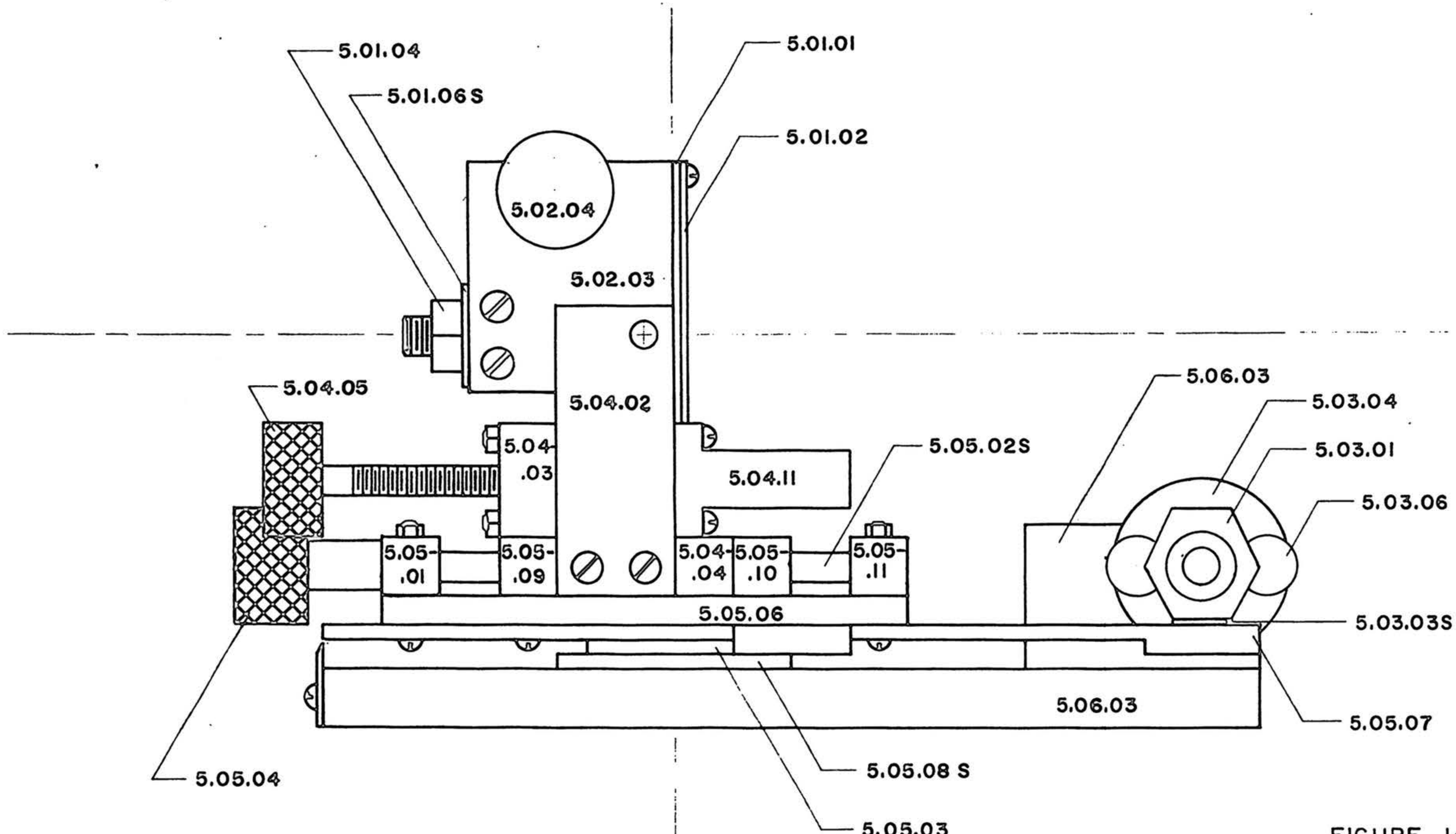


FIGURE 14.01.00 B
ORIGINAL GRATING MOUNT

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 8/5/56	GRATING MOUNT — SIDE VIEW
	ASSEMBLY No. 5.00.00

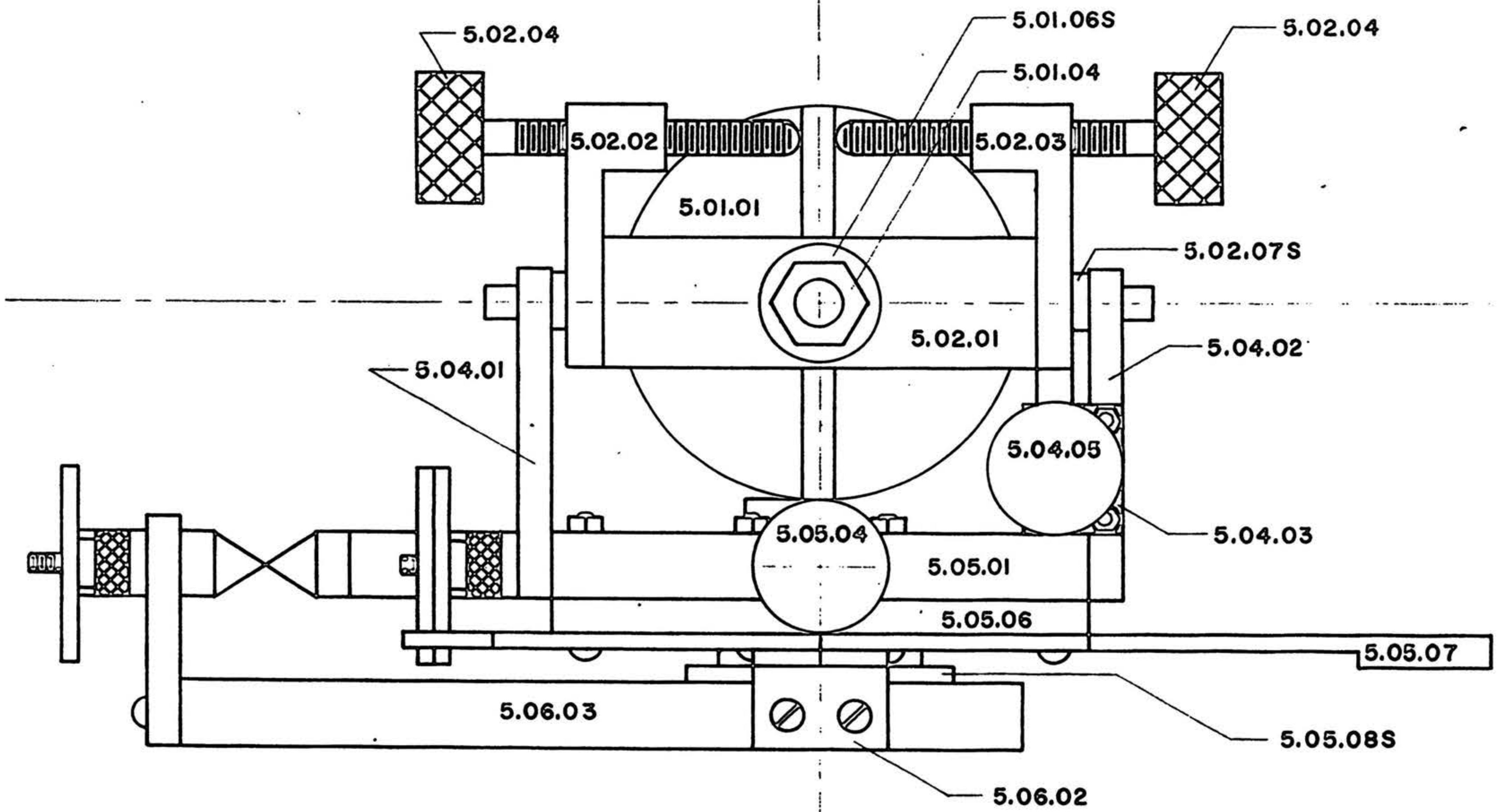


FIGURE 14.01.00C
ORIGINAL GRATING MOUNT

M.S.M. PHYSICS DEPT.	
VACUUM SPECTROGRAPH	
JKH 8/5/56	GRATING MOUNT-REAR VIEW
	ASSEMBLY No. 5.00.00

mechanism shown caused excessive bounce of the grating drive arm as a result of non-symmetry of the two universal joints in the drive shaft. A vertical motion restraining guide was added by Mr. Bob Peercy and Mr. Richard Schoen, but this failed to give entirely satisfactory results.

The Grating Drive Unit (5.07.00) was completed except for installation of the limit switches and drive motor. The Grating Drive Control Unit (5.09.00) was designed and parts obtained, but was not assembled.

6.00.00: Film Holder and Mask

The Film Holder (6.01.00) parts were fabricated but not assembled.

The Mask Assembly (6.02.00) was designed, but parts were not fabricated.

The Film Positioner (6.03.00) was completed.

The Film Drive Linkage (6.04.00) was designed, but parts were not fabricated.

7.00.00: Mounting Platform

The Mounting Platform (7.00.00) was completed. However, errors by the shop in part fabrication and general failure to observe the specified assembly instructions resulted in a usable but unsatisfactory unit. An entirely new platform should be constructed with the proper attention paid to tolerances and the specified assembly procedure.

8.00.00: Vacuum Chamber

The vacuum chamber (8.00.00) was completed and proved to be entirely satisfactory. The design and construction precautions apparently resulted in a leak free system from the very beginning. An inside pressure of 1×10^{-5} mmHg (measured on the Phillips ionization gauge) was achieved at the initial pump down using three small and somewhat questionable fore pumps. (The large pump was not available.) With the system closed off after pump down, the inside pressure had risen to only 80 microns when checked two hours later.

9.00.00: Mounting Stands

Both the vacuum chamber support stand (9.01.00) and the overhead track assembly (9.02.00) were completed and installed.

10.00.00: Grazing Incidence Equipment

Although the basic grazing incidence layout was completed and the necessary provisions were built into the grating mount, the light source adapter line and the mounting hardware for the plate holder were not designed.

11.00.00: Pumping System

The pumping system was completed except for the installation of the main fore pump control box (11.05.00S1) on the spectrograph control panel rack. (An available wall box in the lab was used.) Lack of available switches prevented the installation of a water pressure switch to cut off the diffusion pump in the event of water failure and a fore pump line vacuum switch to cut off the diffusion pump in the event of a fore pump failure.

The pumping system was checked out by Mr. Richard Schoen. Using the 11.03.00 fore pump, the pressure at which the diffusion pump can be turned on is normally reached in approximately ten minutes. Warmup and outgassing of the diffusion pump requires another thirty-five minutes. Outgassing time for the vacuum chamber walls depends, of course, on the ultimate pressure desired. An inside pressure of less than 0.1 micron can be reached in less than one hour. When the pressure drops below 0.1 micron, strong outgassing, apparently from the walls, comes into play and slows the pump down rate. Starting from atmospheric pressure and the diffusion pump not having been on in some time, the system has been pumped down to an inside pressure of 0.028 microns within a three hour time period.

A noticeable hump was observed in the pump down curve between 25 and 30 microns. This is a point in which neither the fore pump or diffusion pump is efficient. The use of a booster pump to eliminate this pump was considered, but ruled out on the basis of cost.

12.00.00: Pressure Gauges

The Phillips and thermocouple gauges were installed and the lines were run to the instrument racks. The thermocouple gauge control panel was completed and installed. An ionization gauge control panel was installed in the instrument rack, but the gauges were not installed.

13.00.00: Power Distribution System

All of the power distribution panels were completed and installed.

14.02.00: Recommendations

14.02.01: Completion of Instrument

Completion of the instrument in accordance with the design presented in this thesis is recommended. The existing grating mount should be reworked to the design described in section five. As explained in section seven, the mounting platform was not constructed in accordance with the series 7.00.00 drawings and is unsatisfactory. A new platform should be fabricated.

14.02.02: Vacuum Precautions

In order to minimize rusting of the inside walls of the vacuum chamber, the chamber should be kept pumped down at all times when not in use. Operation of a fore pump every day or so for a few minutes should be sufficient to maintain the necessary vacuum.

Outgassing of the chamber walls considerably lengthens the pump down time for pressures below 0.1 micron. Nickel or chrome plating of the inside walls of the vacuum chamber would be desirable if operation at lower pressure is desired. Some of the apparent outgassing may be the result of forced leakage past the inner "O" rings. The pump out ports have not been drilled in the flanges. These port holes should be drilled to relieve pressure between the rings.

14.02.03: Additions to Instrument

In order to maintain the basic instrument configuration and extend its useful life, utilization of existing access ports and mounting provisions is recommended for the installation of any new equipment added to the basic instrument. With reasonable care, the basic instrument should remain useful for many years.

15.00.00: BIBLIOGRAPHY

15.01.00: Books

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15.02.00: Periodicals

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16.00.00: VITA

J. Kirston Henderson was born on March 3, 1932, at Purdy, Missouri. He was graduated from the Purdy High School, Purdy, Missouri, in 1950.

Mr. Henderson was graduated from Drury College, Springfield, Missouri, in May of 1954, with the Bachelor of Arts Degree in Physics.

Following his graduation from Drury College in 1954, Mr. Henderson was employed in the engineering department of McDonnell Aircraft Company in St. Louis, Missouri.

Mr. Henderson enrolled in the Graduate School of the Missouri School of Mines and Metallurgy in September of 1954.

During the summer of 1955, he was employed as an Aerophysics Engineer by Convair, A Division of General Dynamics Corporation, in Fort Worth, Texas. After completion of the academic requirements for the degree of Master of Science, except for the completion of a thesis, Mr. Henderson returned to Convair in Fort Worth and was promoted to the position of Senior Aerophysics Engineer in June of 1958.

On February 4, 1960, Mr. Henderson married Miss Dot Adams of Fort Worth, Texas.